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WHITE-PINE BLISTER RUST: A COMPARISON OF EUROPEAN WITH NORTH AMERICAN CONDITIONS

BY

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Senior Pathologist, Office of Forest Pathology, Bureau of Plant Industry

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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INTRODUCTION

In 1909 the discovery of the white-pine blister rust (*Cronartium ribicola* Fischer) in imported young eastern white pines (*Pinus strobus* L.) focused attention upon this serious disease of some of our most important timber trees. In 1911 the writer published an account of the distribution and hosts of this disease in Europe and the known means of combating it (*154*).[1] In the following years extensive investigations were made into the life history of the parasite causing it, and field tests of various methods of combating it were made. In 1922 a comprehensive account of all of the known investigations concerning the disease was published (*160*). These two publications supplemented each other and were written without personal investigation of European conditions. They brought together the published information that was available. The wide distribution of the disease in Europe and the volume of scattered publications concerning it indicated clearly that personal investigation in various countries

[1] Reference is made by italic numbers in parentheses to "Literature cited," p. 48.

So, too, are those pitch pines of the group Parapinaster, which have some of the characters of the white pines, indicating close relationship to them and possible susceptibility to this fungus. The numbers following the names of localities indicate the number of trees seen. Where fairly recent data concerning them in places not visited are given in literature, they are included for the sake of completeness.

Pinus albicaulis Engelmann:

England, Crawley 2; *France*, Angers; *Sweden*, Hemso, near Harnosand (Moir).

Pinus aristata Engelmann:

England, Crawley 3; *France*, Massy-Verrieres 1, Nogent-sur-Vernisson; the *Netherlands*, Putten 1; *Switzerland*, Zurich 1.

Pinus armandi Franchet:

England, Crawley 3, Kew 1; *France*, Massy-Verrieres 1, Nogent-sur-Vernisson 1 (Moir); *Scotland*, Edinburgh 25.

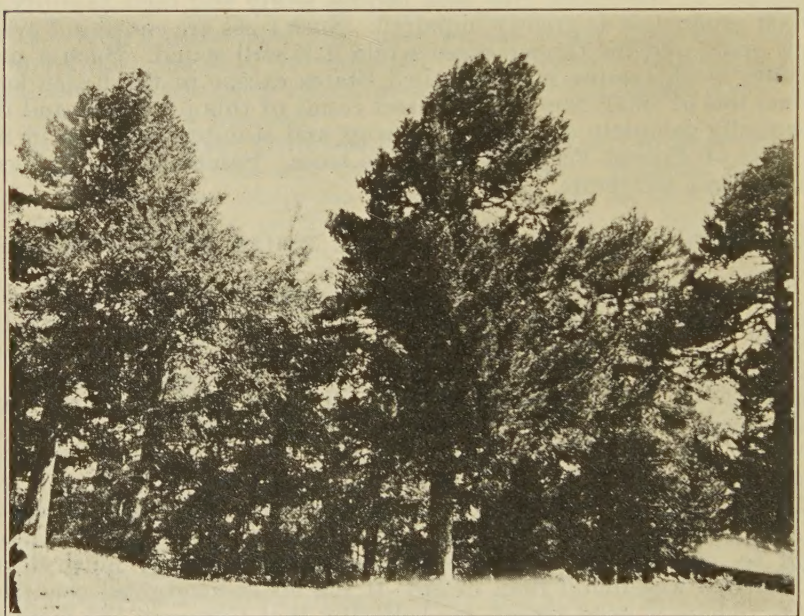

FIG. 1.—*Pinus cembra* near the upper limit of the species, in mixture with *Larix europea*. Both species go to timber line. The trees are several hundred years old. (Near Termignon, France)

Pinus ayacahuite Ehrenberg:

Belgium, Groenendael 7 (Moir); *England*, Hollycombe (Moir), Horsham 1 (Moir); *France*, Angers 1, Massy-Verrieres 1, Nogent-sur-Vernisson 1 (Moir); *Scotland*, Stobo 2.

Pinus balfouriana Balfour:

Belgium, Groenendael 1; *England*, Crawley 1; *France*, Angers 1, Nogent-sur-Vernisson; *Germany*, Tharandt; the *Netherlands*, Putten 1, *Scotland*, Edinburgh 4; *Sweden*, Upsala 1 (Moir).

Pinus bungeana Zuccarini:

England, Crawley 1, Kew 3; *France*, Angers 1, Nogent-sur-Vernisson 1; *Italy*, Vallombrosa 1; the *Netherlands*, Putten 1.

Pinus cembra:

Native stands of this species were examined near Termignon, France (fig. 1), and near Zurich (fig. 2) (*202*), Interlaken, Zermatt, and Pontresina, Switzerland.

Planted trees were seen at *Belgium*, Calmpthout (Moir), Gedinne one-fourth acre (Moir), Groenendael 2; *England*, Crawley 1; *Finland*, Borga (*173*); *France*, Angers 1, Massy-Verrieres 1, Nogent-sur-Vernisson 6 (Moir); *Germany*, Berlin 20; *Italy*, Vallombrosa 8; the *Netherlands*, Putten 1, Zundert (many small trees in nursery); *Norway*, Oslo 1 (Moir), Jelsa 50 (?) (Moir), Softeland 1 (Moir); *Russia*, Petrograd, several thousand seedlings (*85*); *Scotland*, Edinburgh 25, Murthly 20 (Moir), Stobo 50 trees about 40 feet high said to be the oldest in Great Britain; *Sweden*, Alnarp 200 (Moir), Hemso, near Harnosand 1 (Moir), Lund 1 (Moir), Stockholm (Djursholm) 1 (Moir), Upsala 6 (Moir), Atvidaberg 6 (Moir), Bispgarden 6 (Moir); *Switzerland*, Berne 4, Zurich 6.

Pinus cembroides Zuccarini:

England, Crawley 1; *France*, Angers 1, Massy-Verrieres 1, Nogent-sur-Vernisson 1.

Pinus edulis Engelmann:

England, Crawley, Kew 1; *France*, Angers 1, Massy-Verrieres 1; *Scotland*, Edinburgh 6.

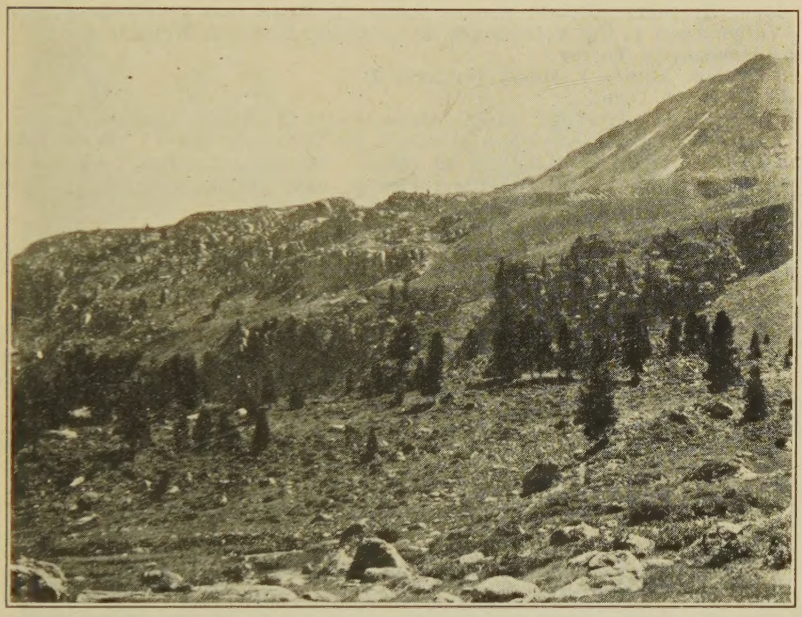

FIG. 2.—*Pinus cembra* at the timber line at Murtschen Alp, Switzerland

Pinus excelsa Wallich:

Austria, Vienna 3; *Belgium*, Calmpthout (Moir), Groenendael 12 (Moir), Tervueren 50 (Moir); *Czechoslovakia*, Prague 12; *Denmark*, Fugelsang (Moir); *England*, Crawley 1, Oxford 2; *France*, Angers 3, Lyon 25, Massy-Verrieres 1, Montpellier 4, Nice 1, Nogent-sur-Vernisson numerous; Orleans, many seedlings (Moir), Valence 6; *Germany*, Berlin 25, Grafrath 50; *Italy*, Como 25, Florence 2, Milan 6, Treviso 1, Vallombrosa 12; the *Netherlands*, Putten 1; *Scotland*, Edinburgh 20, Murthly 1 (Moir); *Sweden*, Alnarp 2 (Moir), Atvidaberg 6 (Moir), Lund 2 (Moir), Upsala 6 (Moir); *Switzerland*, Aarau 1, Aigle 1, Ambri-Piotta 4, Berne 6, Chur 6, Lugano 12, Melide 6; Zurich 6; *Wales*, Lake Vyrnwy 25.

Among the introduced species of white pines, *Pinus excelsa* is next to *P. strobus* in abundance and wide distribution in Europe. It appears to flourish under some conditions where the latter can barely survive. Except for snow breakage, probably due to

the longer needles, it appears to be as promising a forest species as *P. strobus*, but in a more southern range.

Pinus flexilis James:

Belgium, Calmpthout (Moir), Groenendael 6, Tervueren 100; *England*, Crawley 3, Kew; *France*, Angers 1, Massy-Verrieres 1, Nogent-sur-Vernisson 16 (Moir); *Germany*, Berlin; *Italy*, Vallombrosa 1; the *Netherlands*, Putten 25; *Norway*, Softeland 300 (Moir); *Scotland*, Edinburgh 6, Murthly 6 (Moir), Stobo 300 (Moir); *Sweden*, Alnarp 180 (Moir), Lund (Moir), Stockholm 4 (Moir), Upsala 4 (Moir).

Pinus gerardiana Wallich:

England, Cambridge, Crawley 1; *France*, Angers 1, Montpellier 1; the *Netherlands*, Putten 1.

Pinus koraiensis Siebold and Zuccarini:

England, Crawley 1; *France*, Angers 1, Massy-Verrieres 1, Nogent-sur-Vernisson 1 (Moir); *Italy*, Vallombrosa 1; the *Netherlands*, Putten 1; *Scotland*, Murthly 1; *Sweden*, Stockholm 1 (Moir).

Pinus lambertiana Douglas:

Belgium, Calmpthout (Moir),Groenendael 1 (Moir), Tervueren 1; *England*, Horsham (Moir); *France* Angers 1, Nogent-sur-Vernisson 1; *Italy*, Vallombrosa 1; the *Netherlands*, Zundert 20; *Scotland*, Murthly 1.

Pinus monophylla Torrey:

France, Angers 1, Massy-Verrieres 1.

Pinus monticola Douglas:

Belgium, Calmpthout (Moir), Groenendael 1 (Moir); *France*, Angers 1, Massy-Verrieres 1; *Germany*, Grafrath 12, Tharandt (Moir); *Netherlands*, Putten 1; *Scotland*, Balmoral 40 (Moir), Edinburg 6 (Moir), Murthly 50 (Moir), Stobo (Moir); *Sweden*, Hemso, near Harnosand (Moir), Lund (Moir), Upsala (Moir).

Pinus parviflora Siebold and Zuccarini:

Belgium, Groenendael 10, Tervueren 10; *England*, Crawley 1; *France*, Angers 1, Massy-Verrieres 1; *Germany*, Grafrath 1; *Italy*, Vallombrosa 1; *Netherlands*, Putten 1; *Scotland*, Edinburgh 6, Murthly 2 (Moir).

Pinus peuce:

Belgium, Groenendael 10 (Moir); *Czechoslovakia*, Prague 6; *England*, Crawley 3; *Finland*, Borga 175 (*173*); *France*, Massy-Verrieres 1, Nogent-sur-Vernisson 2; *Germany*, Grafrath 15; *Italy*, Vallombrosa 1; *Netherlands*, Putten 1; *Scotland*, Edinburgh 6.

Pinus pinea L.:

France, Nogent-sur-Vernisson 1; *Netherlands*, Putten 1; *Italy*, Vallombrosa 1.

Pinus strobus:

Belgium, Bievres 100 (Moir), Calmpthout (Moir), Fraihout 6 (Moir), Gedinne 100 acres (Moir), Groenendael 100 (Moir), Luxemburg 1 (Moir), St. Hubert 7 (Moir), Tervueren 100; *Czechoslovakia*, Kouty, plantation of several acres; *Denmark*, Bornholm 100 acres, Silkeborg 6,000 trees (Moir), Stubbekjobing 1,000 trees (Moir); *England*, Attleboro 20 (Moir), Bagshot 50 acres (Moir), Crawley 25, Durham 3,000 (Moir), Oxford 3 acres (Moir); *Finland* (*100*); Borga 175 (*173*); *France*, Angers 3, Chagny 1, Epinal 144 acres (Moir), Lyon 25, Massy-Verrieres 1, Nogent-sur-Vernisson 100 (Moir), Versailles 6; *Germany*, in Bavaria in 1905 there were about 15,000,000 of this species planted in the state forests of this Province alone (*111*); in Baden in 1906 there were nearly 700 acres of this species, Berlin 12, Grafrath 50; *Italy*, Chiasso 6, Como 50, Melide 100; *Netherlands*, Putten 100, Zundert, many in nurseries; *Norway*, Aas 2 (Moir), Bygdo 2 (Moir), Oslo 6 (Moir), Egersund 150 (Moir), Fjosanger 20 (Moir), Jelsa 1.2 acres (Moir), Kyrrefjord many (Moir), Softeland (Moir), Stavanger (Moir), Trondjhem 250 (Moir); *Scotland*, Balmoral 35 (Moir), Edinburgh 100, Murthly 4 acres (Moir), Stobo 100 (Moir), Thornhill 1 acre; *Sweden*, Alnarp (Moir), Atvidaberg 450 (Moir), Bispgarden 5,200 (Moir), Bjurfors 2 (Moir), Boda 20 acres (Moir), Falun 10 (Moir), Hemso 1 (Moir), Kalmar 3 (Moir), Ljungbyked 2 (Moir), Lund 6 (Moir), Omberg one-half acre (Moir), Stockholm 100 (Moir), Upsala (Moir); *Switzerland*, Aarau 1 Aarburg 1, Ambri-Piotta 6, Ballinzona 6, Berne 50, the city forest of Berne in 1921–22 had over 4,000 trees of this species 60 years or more old. (Fig. 3.) Many more younger ones were seen by the writer. Chur, a few, Faido 50, Fribourg 1, Interlaken 50, Langenthal, thousands of all ages up

to 85 years naturally regenerating in abundance, Lugano 150, Meschino 4, Meiringen 100, Murten (Morat) 100,000 up to 90 years old, Olten, Paschiavo 2, Rapperswil (over 600 have a diameter exceeding 24 cm; over 4,000 were set out in 1920 and 1921 to fill openings made by wind; about 100 trees were planted in 1804–5; abundant natural regeneration so that the total number must be many thousands) (*5*, *101*). Redi-Fiesco 6, Spiez 1, Tessereto 50, Wynigen, Zofingen in 1919 over 3,600 trees 40 cm. or more in diameter. Zollikon 6, Zurich 50. It is safe to say that the Swiss forests have *P. strobus* by the million. They appear to have some of the oldest trees growing in forest conditions. There are many thousands of trees more than 50 years old (*5*).

Willkomm (*200*) says that as a park tree *P. strobus* has been extraordinarily widespread and acclimated, especially in England, northern and middle France, Belgium, Switzerland, Germany, Austria, Poland,

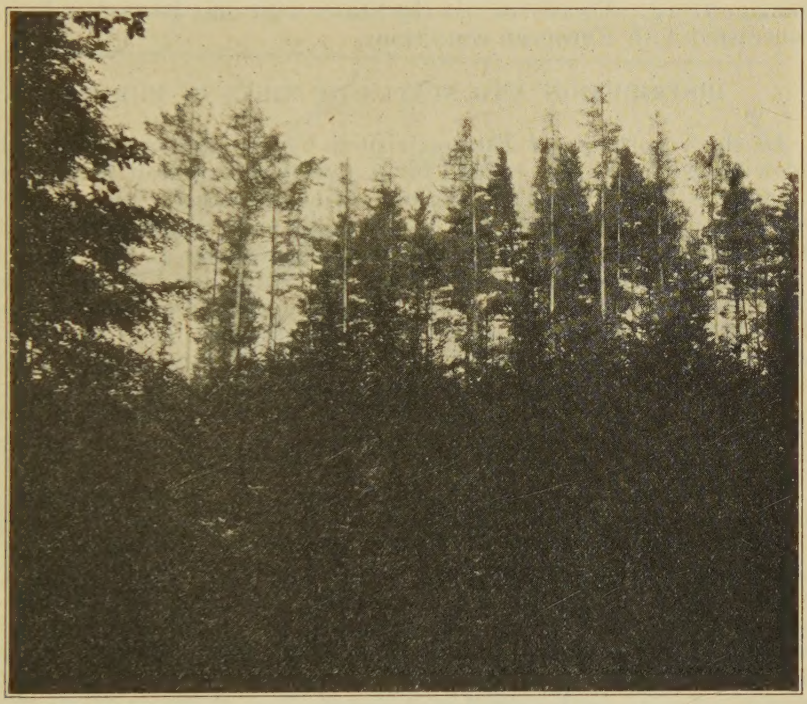

FIG. 3.—*Pinus strobus* at Berne, Switzerland. These trees are about 90 years old

Lithuania, and West Prussia. In Germany and Austria it has been grown in forests, even in large stands of old trees of this species. This statement is borne out by the findings in those countries which were visited.

The following estimates have been made of the amount of *P. strobus* in Europe, so that its importance may be understood:

Austria, 31,500 trees (*205*); Belgium, 5 acres; Czechoslovakia, 20 acres; Denmark, 200 acres (Moir); Finland, a few ornamental trees; France, 300 acres (Moir); Germany, 20,000 acres; Great Britain, 50 acres; Italy, 5 acres; the Netherlands, 2 acres; Norway, scattering ornamental trees; Russia, scattering ornamental trees; Sweden, 100 acres (Moir); Switzerland, 1,000 acres.

The figures include only trees past the seedling stage. This estimate is a mere guess, but probably there are not over 50,000,000 such trees in all Europe (excluding Russia) in an area of nearly 2,000,000 square miles. The larger part of these trees are in groups in forests, so that (excluding those in the forests) there probably is not more than one tree of *P. strobus* per square mile. Even ornamental trees are apt to occur in groups, so that there are numerous areas of many square miles each where there are none. These statements show the uneven distribution of *P. strobus* in Europe.

The distribution of the white pines in North America has already been published (*160, fig. 2*). The natural ranges of these trees include large areas where the white pines are numerically prominent in the forests. Because of the huge numbers involved, possible damage from a disease such as the blister rust may be tremendous as contrasted with European conditions.

DISTRIBUTION AND STATUS OF RIBES IN EUROPE

In those portions of Europe visited by the writer Ribes bushes growing wild are rare except for a few localities well back in the mountains. At Termignon, France, wild gooseberry bushes (*Ribes uva-crispa* L.) were abundant in old fields and pastures by the edge of the forest. At Zermatt, Switzerland, *R. alpinum* L. was plentiful in old fields by the highway; in the Upper Engadine Valley (Rosseg-thal) *R. petraeum* Wulfen was abundant on the loose stony slopes. Except for relatively few similarly scattered localities, wild Ribes in western Europe appear to be limited to single rare escaped bushes of the cultivated species (*114*); at least the experiences of Moir and the writer would lead to this conclusion. In general, the wild-growing Ribes of Europe are negligible in their influence upon the distribution of *Cronartium ribicola* (*14, 72, 114*).

The cultivated Ribes, on the other hand, are so generally grown as to be termed ubiquitous except in central and western France and the Mediterranean Basin. While the gooseberry (*R. reclinatum* L.) and red and white currants (*R. vulgare* Lam.) are much grown, the black currant (*R. nigrum* L.) is probably present in the gardens in greater numbers than any other species and certainly is the most popular one. It is safe to say that it is present in three-fourths of all of the gardens of that part of northern Europe visited by the writer. To it can be attributed practically all the damage from *Cronartium ribicola* seen by the writer in Europe. For instance, Rostrup (*135*) says that the blister rust is especially prevalent in that part of Denmark where *R. nigrum* is grown in greatest profusion. Moir (*113*) also implies that in his opinion *R. nigrum* is responsible for practically all of the disease in pines in western Europe.

De Candolle (*18*) says that *R. nigrum* is said to grow wild in northern Europe from Scotland to Lapland and southward to northern France and Italy; in Bosnia, Armenia, throughout Siberia, etc.; also that it often becomes naturalized, as, for instance, in the center of France. The writer did not see it growing wild in Europe and has never seen it growing wild in North America except where it was first planted by man.

In contrast with the prominence of cultivated Ribes and the negligible numbers of wild Ribes in Europe, there is in North America

a relatively great abundance of wild species and considerably smaller numbers of the cultivated Ribes. In Europe the cultivated black currant, *R. nigrum*, is the principal factor determining the severity of attack of the disease. In North America the wild Ribes commonly are the controlling factor.

ORIGIN AND SPREAD OF WHITE-PINE BLISTER RUST

In 1854 Dietrich found the first known specimens of *Cronartium ribicola* upon Ribes (with the possible exception of a specimen collected by Lasch in Driessen, Germany, about 1842 (*89*) and said by Sydow (*167*) to be this fungus) and also upon *Pinus strobus* in the Baltic provinces of Russia (*31*, *154*). In the three decades beginning in 1860 it evidently swept over northern and most of western Europe. It has permeated Europe as completely as the distribution of its

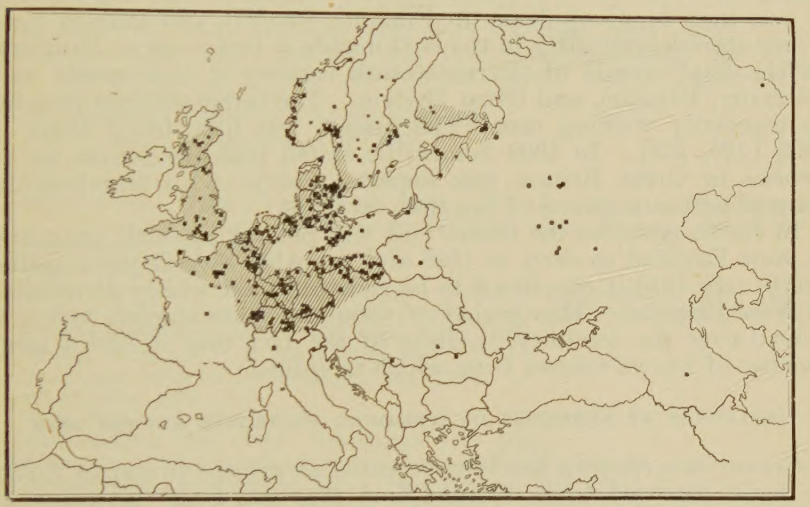

FIG. 4.—Map of Europe, the shaded portion showing the area which is generally infected by *Cronartium ribcola*. Known scattered infections are indicated by the isolated spots

hosts will allow (*160*). (Fig. 4.) As shown by the preceding discussion of these hosts (Ribes and five-needled pines) and their distribution in Europe, both groups are widely and quite generally distributed except in the Mediterranean Basin and in central and southwestern France (*33*, *48*, *140*). It appears that in Europe as well as in North America the climate required by the five-leaved pines is exactly that best suited to the Ribes; consequently, wherever the five-leaved pines are found, Ribes are also found. In Europe both are very largely introduced. The distribution of both is scattered and discontinuous, but both are general favorites, so that plants of both groups are usually found nearly everywhere that the climate and soil are favorable for them. Outside the forests the white pines are usually present in smaller numbers and are much more widely separated than the Ribes. The known long-distance dissemination of the fungus by its aeciospores (*14*, *36*, *120*, *177*), together with the abundant and wide distribution of diseased pine seedlings from in-

fected nurseries, explains the rapid spread and almost universal presence of this fungus in western and northern Europe wherever *P. strobus* occurs.

Although the writer's travels in Europe necessarily could not allow a thorough examination even of those parts which were visited, and touched only what may be called northwestern and middle Europe, yet he believes that the shaded area in Figure 4 may safely be called generally infected. While the blister rust occurs in Europe on other five-needled pine, its common pine host there is *P. strobus*. As far as the discontinuous distribution of this introduced species will permit, the blister-rust disease has nearly reached what may be called, for want of a better term, the saturation point within the above-mentioned area.

A feature of the spread of white-pine blister rust, as far as known, is its relative rapidity. For instance, its first known outbreaks in Europe were in the sixth and seventh decades of the last century. It was then found epidemic in Finland, Sweden, and Prussia upon *Pinus strobus*, and early in the next decade it broke out in Denmark. In the final decade of the nineteenth century it had spread over Germany, Belgium, and Great Britain. The latter country presents an especially striking case. The disease was first found there in 1892 (*126*, *127*). In 1909 Somerville stated that the future for *P. strobus* in Great Britain was hopeless (*153*). This situation developed within a period of less than 20 years.

In North America the blister rust was present in small quantities in New England as early as 1898 and probably several years earlier (*160*). In 1916 it was found to be generally and widely distributed in New England. This period of about 20 years elapsed before it spread over the territory, in spite of the fact that it had a large number of known centers from which to spread.

INFLUENCE OF NURSERIES IN SPREADING WHITE-PINE BLISTER RUST

Cronartium ribicola has been reported as present in Japan (*168*). It is also reported from central China (*21*) and from two points in Siberia (*172*). These widely separated occurrences in territory which is still far from being thoroughly explored botanically appear to the writer to indicate that the fungus originated in northern Asia (*160*). This opinion is held by Tubeuf also (*181*). Assuming that this is true, how could it reach Europe, become generally distributed there, and finally reach North America and become established here in both the northeastern and Pacific coast forest regions? If it was native in northeastern Asia it is reasonable to expect it to spread in the course of time throughout the range of its hosts there. From Siberia, which is well within the range of *Pinus cembra* and of some species of Ribes, early Russian explorers and travelers would easily account for its being carried into some botanic garden of Russia (*92*). Several large gardens existed in Russia about 1810. There are published lists of plants in large gardens located at Cracow (*27*), Krzemieniec (*11*), Moscow (*47*), and Petrograd (*128*), all listing *P. strobus* among their conifers. In the first half of the nineteenth century there were about 40 large botanic gardens in Europe of which lists of their plants had been published. Some of the earliest gardens of Europe published no complete list of their plants, so that we know

but little of their contents. Definite records have been found of the presence of *P. strobus* at various places in Europe at about the time of the discovery of *C. ribicola*, or in the preceding 50 years, as follows:

Austria: Carintha, 1846 (*70*); Schonbrunn, 1816 (*12*); Vienna, 1842 (*39*).
Belgium: Aywaille, 1797 (*26*); Franc-Warret, 1892 (*26*); Ghent, 1802 (*25*); *Maizeret*, 1829 (*26*); Malines, 1809 (*197*); Scy, 1840 (*26*); Solre-St-Gery, 1829 (*26*); St. Hubert, 1826 (*26*).
Czechoslovakia: Bohemia, fellings of this species made in 1838 (*1*).
Denmark: Copenhagen, 1813–1819 (*73*).
France: 1770 (Moir); Besancon, 1805 (*115*); Fontainebleau, 1553 (*10*); Grenoble, 1857 (*186*); Grignon, 1837 (*122*); Montpellier, 1805 (*19*); Paris, 1804 (*30*); Strassburg, 1807 (*187*); Tarascon, 1831 (*4*); Versailles, 1843 (*123*).
Germany: 1750, generally introduced into northern Germany (*64*); 1800, widely spread in the forests of Germany (*35*).
Anhalt: 1780 (*194*); Dessau, 1828 (*144*); Worlitz, 1828, implies that trees of this species had been there 70 years (*144*).
Baden: 1760 (*194*); Carlsruhe, 1825 (*65*); Mannheim, 1809 (*206*).
Bavaria: 1758 (*194*); Ansbach, 1827 (*111*); Branunschweig, 1825 (*64*); Memmingen, 1820 (*103*); Munich, 1821 (*166*); Tharandt, 1866 (*199*); Trippstadt, 1795 (*96*).
Brandenburg: 1750 (*194*); Berlin, 1809 (*198*).
East Prussia: Konigsberg, 1812 (*146*).
Hamburg: 1836 (*118*).
Hanover: 1760 (*194*); Gottingen, 1753 (*59*).
Hesse-Nassau: 1760 (*194*); Cassel, 1785, there were then over 20,000 trees (*112*); 1790, there were over 30,000 trees (*13*); Marburg, 1851 (*195*).
Pomerania: 1770 (*194*).
Posen: 1810 (*194*).
Rhine Provinces: 1740 (*194*); Cologne, 1806 (*171*); Dusseldorf, 1834 (*139*).
Saxony: 1770 (*194*); Leipzig, 1790, already grown there for many years (*8*).
Schleswig-Holstein, 1810 (*194*); Kiel, 1822 (*192*).
Silesia, 1800 (*194*); Dresden, 1824 (*71*).
Thuringia, 1768 (*194*); Weimar, 1804 (*130*).
Westphalia, 1760 (*194*).
West Prussia, 1820 (*194*).
Wurttemberg, 1805 (*194*); Hohenheim, 1779 (*134*).
Great Britain: 1705, introduced into general cultivation (*9, 38*).
The Netherlands: Amsterdam, 1821 (*189*); Leyden, 1818 (*15*).
Italy: Florence, 1818 (*124*); Modena, 1820 (*74*); Naples, 1813 (*170*); Padua, 1842 (*188*); Palermo, 1793 (*56, 175*); Pisa, 1804 (*174*); Rome (*2*); Turin, 1813 (*6*); Venice, 1847 (*138*).
Norway: Early in nineteenth century (Moir); 1860 by the forestry service (Moir).
Poland: Krakow, 1864 (*27*); Krzemieniec, 1811 (*11*).
Rumania: Bucharest, 1871 (*54*).
Russia: Moscow, 1812 (*47*); Petrograd, 1815 (*128*).
Sweden: Early in the nineteenth century (Moir).
Switzerland: Berne, 1810–20 (*5*); Lenzburg, 1840 (*5*); Murten, 1830 (*5*); Pampigny (Vaud), 1829 (*5*); Rapperswil, 1804-5 (*5*); Canton Neuchatel, 1849 (*5*).

These data on the distribution of *Pinus strobus* in Europe in the first half of the nineteenth century are very incomplete because of the lack of publications giving definite information except in the case of more prominent botanic gardens and of relatively few instances in forestry literature. Consideration of these definite data and the probable unmentioned distribution shows that the stage is well set for the rapid distribution of a virulent disease of *P. strobus* over most of Europe at this time.

Early conditions were very favorable for the rapid distribution between different countries of Europe and Asia of such a disease

as *Cronartium ribicola* in infected plants of *P. strobus* or Asiatic five-needled pines. In the fourteenth and fifteenth centuries the Hanseatic League monopolized the commerce of the entire region from Livonia to the Netherlands in Europe and was the grea' communicating agency between Asia and Europe (*95*). The League had great distributing centers at London, Bruges, Lubeck, Bergen, and Nizhni Novgorod. While travel was necessarily slow, it was nevertheless constantly maintained even at this early day. Merchants traveled extensively, but comparatively few people of the other classes did so. There was free communication by official representatives of the rulers, and much of the earlier movement of living plants and seeds was in the nature of personal exchanges between rulers. The earlier botanic gardens were owned by prominent physicians, or rulers, or nobles intimately associated with the rulers. Thus the earlier exchanges of plants were concentrated in narrow channels leading from one botanic garden to another. In the eighteenth century Linnaeus's work (*76*), resulting in the coordination of names of the plants and animals, and the activities of his pupils undoubtedly led to a stimulation of botanical exploration and collection in all parts of the world. Between 1750 and 1850 there was probably the greatest interest in forming great collections of living plants in botanic gardens that has ever developed. Communication between countries at this time was relatively free and untrammeled. In this respect, again, conditions were favorable for the rapid distribution of infected *P. strobus* plants from a single center of infection to great distances, where conditions would be most favorable for the disease to establish itself, because of the presence of some species of Ribes in the botanic garden to which the infected pine plants were taken.

It appears that *Cronartium ribicola* easily may have been, and very likely was, distributed over Russia and thence to western Europe in young infected trees of *P. strobus*, since this species has been its favorite pine host in Europe. A single infected nursery in early days could easily do this. In fact, it appears that this is what has actually been done in several countries in Europe.

For instance, Calmpthout, Belgium, has long been an important nursery center, producing forest-tree seedlings as well as general nursery stock. The blister rust was found there in 1898 (*117*). It is likely that it was present in the vicinity some time before then. Young trees of *P. strobus* and other white pines were certainly produced there in quantity (*91*) and distributed in the neighboring region, including Germany. In 1920 infected trees of *P. strobus*, *P. lambertiana*, and *P. monticola* were seen at this place (Moir). Much stock went formerly to Germany and to North America, especially to an eastern Massachusetts firm (Moir). It is morally certain that the blister rust was thus distributed to other parts of Belgium, Germany, and other European countries, and quite likely to North America Inspections made after 1909 in New England of various plantations of *P. strobus* which came from the above-mentioned Massachusetts nursery before 1909 showed plainly that the trees had been diseased for several years, and presumably ever since being imported. Similar findings were made upon young stock of *P. strobus* imported from nurseries at Ussy, Orleans, and Chatenay, France (*154*).

But the plainest case was that of J. Heins Söhne, of Halstenbek, Schleswig-Holstein, Germany (*154*). No less than 226 different lots of young *P. strobus* from this firm were found in North America so attacked by blister rust that there could be no doubt that the infection took place in their nurseries before the stock was imported (*154*). Fürst, in a special article upon the Heins' nurseries, states that yearly many million forest plants were sent to all Germany and especially to the southern part (*49*). As early as 1897 Tubeuf stated that this disease was being freely distributed over Germany by infected nursery stock from Halstenbek (*176*), and he evidently attempted to have some control put upon this unrestricted traffic, but the nursery interests were strong enough politically to prevent this being done. They even went so far as to try to have their nurseries declared free of blister rust by a man prominent enough to allay the rising alarm and finally succeeded in getting such statements published (*49, 131, 145*). Tubeuf (*178*), however, promptly showed that it is impossible for any person to ascertain the absence of the disease in an infected nursery. About 1900 Tubeuf said that blister rust occurred here and there over Germany, but that it was evidently much more prevalent than the available reports would indicate. In 1922 he told the writer that it was generaly distributed throughout Germany, a fact also found from the published reports concerning it. That this early, wide distribution was due to unrestricted shipment of infected young white pines from nurseries, including those at Halstenbek, he and others have stated repeatedly. There can be no doubt that nursery stock was the means of infection reaching North America (*154*).

The latest outbreak in the Pacific Northwest is directly traceable to young *P. strobus* imported from Ussy, France, in 1910 (*28*). In England in 1898 Smith stated that *Cronartium ribicola* was common on *P. strobus* and was being distributed there by German nurseries in imported stock (*148*). The evidence is complete that European nurserymen have very largely, at least, distributed this disease over the range of the white pines, which are among the most promising species for reforestation. They have, so far as Europe is concerned, killed the goose that laid golden eggs for them, as *P. strobus* is surely being exterminated in much of Europe and its use is practically discontinued in most European countries, while importation of pine nursery stock into the United States is prohibited indefinitely.

DISSEMINATION OF SPORES OF CRONARTIUM RIBICOLA

An important feature of the disease in Europe is the much greater distance that infection has spread from Ribes to pines than it has done in North America.

In considering the matter of distance between hosts that *Cronartium ribicola* may be disseminated, one must keep clearly in mind what spore form is under consideration, for each spore form has its peculiar characteristics which determine in gunnery parlance its "effective range." Here in North America considerable attention has been given to these matters, i. e., to factors controlling distribution of the spores (*120, 149*), agencies distributing them (*28, 29, 36, 51, 52, 107, 120, 156, 160, 190, 193*), their longevity under natural con-

ditions (*34*, *159*, *160*, *164*, *165*), distance from source that they may be spread naturally (*36*, *52*, *105*, *107*, *114*, *120*, *150*, *151*, *157*, *158*, *160*, *190*), etc. Some are the most difficult problems in plant pathology, and some are insoluble from the scientific standpoint because of the numerous extremely variable factors involved, so far as this parasite is concerned.

Experience in North America has shown that the aeciospores may be blown by wind for miles and start infection upon Ribes leaves; how many miles is very uncertain, as it obviously is impossible scientifically to trace such spores through their more or less erratic course in the air for long distances and to ascertain for what distance they may survive and be able to cause infection upon Ribes leaves. Yet this has been done for distances up to 1¼ miles with scientific accuracy, with less accuracy up to 7 miles (*150*), and still more recently, by the elimination of other factors, upwards to hundreds of miles (*120*). No scientifically accurate work upon this problem of the effective range of the aeciospores of *Cronartium ribicola* was done in Europe by either Moir or the writer except for short distances, but it may be said that Tubeuf (*177*) got infection of Ribes up to 500 meters from diseased *Pinus strobus*. Recently Jorstad (*78*) states that heavy infection of black currants has occurred in Norway at a distance of at least 2 kilometers from the nearest white pines. The general experience indicates a very wide distribution of aeciospores there as well as here, *Ribes nigrum* often being infected miles from any known white pines.

The effective range of the uredospores of the blister-rust fungus is limited to hundreds of yards rather than miles (*34*, *105*, *121*, *150*, *160*, *164*), but this appears to be due to their low longevity rather than to the shortness of distance that they may be disseminated (*34*, *164*). In Europe practically nothing has been done upon this problem.

The teliospores of this fungus are not normally distributed, but must germinate in situ and produce sporidia, which, however, are distributed freely by the wind and other agencies. The telia-bearing Ribes leaves may fall and be blown about, but this distribution is commonly operative for but short distances.

The effective range of the sporidia is a difficult thing to determine. Observations of actual distances between infected white pines and the Ribes from which infection came appears easy and simple. In practice here in North America, wild Ribes are so nearly omnipresent that exceedingly few places have been found which gave data of scientific value. The early removal of Ribes to control the disease has interfered with the securing of such data in nearly all instances that were likely to be of value. Such observations have shown that pine infection usually occurs only within 200 yards, but may occasionally occur up to 600 yards' distance (*158*, *160*). It is likely that this is not the extreme limit. It is very difficult to catch viable sporidia at varying distances from a given center of production, but sporidia-catching attempts have given results up to 600 feet (*158*). Studies upon the longevity of sporidia in the air at various degrees of moisture show that they may live in air of favorable moisture up to 26 hours without free water and then readily germinate when free water is supplied (*165*). This indicates that they are distributed oc-

casionally for long distances in a viable condition. This conclusion also follows from certain European experiences.

A study of conditions in Europe by Moir, and later by Boyce and the writer, shows that in some places heavy infection of *Pinus strobus* has occurred at distances of two-thirds of a mile from Ribes, the infecting Ribes being *R. nigrum*. In these cases it was very evident that tremendous quantities of sporidia were produced by *R. nigrum* bushes in gardens throughout the country surrounding the forests. The result is that an impalpable cloud of sporidia (at favorable times) covers the entire country for miles. The forest is a mere island of nonsporidial producing vegetation over which the surrounding sporidial cloud necessarily blows, no matter from what direction the wind may be. Nothing approaching these conditions on a like large scale has ever been seen by the writer in North America and actual experience here shows that 200 yards is usually a sufficient distance to prevent serious damage to a white pine (*P. strobus*) stand by all Ribes but *R. nigrum*. Whether this will hold true for *P. monticola* is not certain, but to date it appears to do so. As a result of this extreme condition in Europe, a safety zone about white pine must be several times as wide as experience has shown to be effective in North America.

CONDITIONS NECESSARY FOR INFECTION OF PINES BY BLISTER RUST

Observations of the disease in all of the outbreak areas of North America by many different workers show that the amount of infection of pines which has occurred is not uniform in different years. A large percentage of the total infections in a given locality have started in a certain year or in a few scattered years. Relatively few scattered infections have taken place in the intervening years. This appears to be true also in Europe. This must mean that the conditions necessary for pine infection are peculiar, so that they do not very often recur.

Recent investigations (*165*) show that the sporidia (which cause the infection of pines) may live for 26 hours in air which has a saturation deficit of less than 5 millimeters and a temperature of 60° to 68° F. It has been found that viable sporidia may infect needles of young plants of *Pinus strobus* within 6 hours (*152*) and of older trees within 36 hours (*203*, *204*). Allowing 12 to 20 hours for the germination of the teliospores and the formation of a maximum crop of sporidia and the minimum of 6 hours for infection of needles by the sporidia, it is found that infection of pines may take place in a period of 18 to 36 hours, depending upon the conditions. York and Snell (*203*) found that this period might be about 24 hours with telial material which germinates promptly. A short time must be allowed for the sporidia to be blown from the Ribes leaves to the pine needles. This period is probably quite brief in most cases, so far as can be judged at present. The open air has the humidity necessary for the survival of viable sporidia for any length of time only when the weather is cloudy, foggy, or rainy (*163*). Foggy weather, when the sporidia are being distributed and are infecting pine, is believed to furnish optimum conditions for the sporidia. Heavy infection of pines must occur in nature only after a period of

damp weather long enough to germinate most of the teliospores that are then mature and to allow infection by their sporidia (*163*). This may mean two or even three days of weather with a saturation deficit continuously less than 5 millimeters.

PREVALENCE OF SPORIDIA

As above stated, *Ribes nigrum* of the gardens is believed to be responsible for most of the damage done by the white-pine blister rust in those parts of Europe visited by Boyce, Moir, and the writer (*14*, *114*, *162*). *R. nigrum* produces far more sporidia than any other species at any given time (*169*). In any section of Europe where the disease is prevalent the *R. nigrum* bushes may be situated at a considerable distance from heavily infected *Pinus strobus*, but they are present in such numbers and so generally in the cultivated areas around the forests that there can be no question that, when the weather is favorable, every leaf or needle of the vegetation in the vicinity catches hundreds of the sporidia of the blister rust.

For instance, the island of Bornholm, Denmark, is about 15 miles across. A state forest occupies the middle of the island. *P. strobus* no matter where located on the island, is heavily infected and is being destroyed (*14*, *99*, *114*). Even small groups of *P. strobus* in the midst of extensive spruce stands which are taller than the pines are as heavily infected as those in the open or semiopen locations. It is evident that when conditions favor the production of sporidia, the *R. nigrum* bushes in the cultivated area around the forest produce an inconceivable number of sporidia, which float like fog everywhere. This must result in every needle of every tree receiving its quota of sporidia. The only thing to be wondered at is that *P. strobus* could grow there even for a few years. The same thing is true to a greater or less degree in most of western and northwestern Europe (see fig. 4, showing area which, in the writer's estimation, is generally infected).

INFLUENCE OF CLIMATE ON VIRULENCE OF WHITE-PINE BLISTER RUST

A study of the climate in areas where the white-pine blister rust has been most virulent shows that the disease is distinctly favored by certain climatic factors.

In North America the blister rust has thus far attacked virulently the eastern white pine (*Pinus strobus*) and the western white pine (*P. monticola*). The disease has been especially aggressive on the former in the region including New England, the eastern Adirondacks, and southern Ontario. On *P. monticola* it is virulent in the coast region of British Columbia as far north as the host pine grows.

These two pines are very similar in their characteristics and in their climatic requirements. Kincer (*80*) has summarized the records of the weather for the United States, including precipitation, temperatures, relative humidity, cloudiness, etc. His data for places just south of the international boundary roughly indicate what may be expected of similar sections north of the boundary. This is especially true of the British Columbia coastal region and southern Ontario, which are almost certainly extensions of climatic areas lying just south of them. The similar types of forest on the two sides of

the boundary indicate this quite plainly. Pennington (*120*) has correlated the weather data for British Columbia with the virulence of the disease there. The months from April to September seem to be the time of year when the disease spreads and attacks the pines. In general, it can be said that these two infected areas, although widely separated in actual distance, are characterized by abundant precipitation and cool temperatures in the warm months. Specifically, Kincer (*80*) shows that both the eastern and western areas in the United States have an annual precipitation of 40 inches or more, an average precipitation during the warm months of 18 inches or more, an average of 50 or more days with precipitation of 0.01 inch or more from April 1 to September 30, and an average of 8 inches or more of precipitation in each of the warm seasons—spring, summer, and fall. As would be expected from this abundant and well-distributed rainfall, fairly cool temperatures and high relative humidity characterize the climate of these regions during the warm months.

While these are average conditions, there are exceptional years when precipitation considerably exceeds the normal average in quantity and frequency. There are also years when it is at a minimum. Observation shows that the blister rust, not only in North America (*104*, *160*) but also in Europe (*14*, *53*), has been very virulent in certain years, while most of the time it is relatively mild. Pennington (*120*) has shown that years of heavy infection of *P. monticola* in British Columbia were also years of abundant precipitation, which was well distributed throughout the warm season. It is a matter of common observation in the Northeastern States that years of maximum precipitation were also years when the blister rust spread most aggressively and, on the contrary, dry years were years when the disease was mild. In other words, the average precipitation for these regions appears to be low enough for the disease to maintain itself, but not great enough for it to exhibit its real power.

In Europe the white-pine blister rust is especially virulent on *P. strobus* (the most generally distributed white pine there) practically throughout northwestern Europe and well eastward into central Europe in Germany and Austria. (See fig. 4, which shows the area considered to be generally infected.) A study of the climate of this area, so far as it can be gleaned by a layman from much-scattered sources, shows the following facts.

Kendrew (*79*) says:

> The strong westerly winds blow straight from the warm ocean, which is a more important source of heat to west Europe than the direct rays of the sun and are the cause of the mild, moist, cloudy climate of west and north Europe.

He also divides Europe into four climatic regions—the northwest, central, east, and Mediterranean. The generally infected blister-rust area is included in the first two. He characterizes the northwest region as follows:

> Snow rare; summers cool; rainfall is abundant at all seasons; spring is the driest season and autumn the wettest in most parts of this region; this is one of the cloudiest regions of the earth. Northwest Europe is often cloudy and rainy and does not see the sun for days and even weeks together.

He describes the central region in the following words:

> Though summer is the rainiest season * * *, yet * * * the air is then drier than in winter and evaporation more active. * * * In summer, too, the

sky is least cloudy, but most of central like northwest Europe can be truly described as cloudy in all seasons. It is only when we cross the Alps that we leave the region of gloomy skies.

Hann (*62*) designates the western region of Europe by the name Atlantic and includes in it most of France, Belgium, the Netherlands, northwestern Germany, Denmark, Scandinavia, Great Britain, and Ireland. This is roughly the area of Kendrew's northwest region. Hann (*62*) states that the mean annual precipitation for the Atlantic region is over 30 inches and in much of it over 40 inches. It decreases in the interior as one goes eastward.

Angot (*3*) has published rainfall maps based on records from 1861 to 1890, which appear to be the best general maps for Europe that are

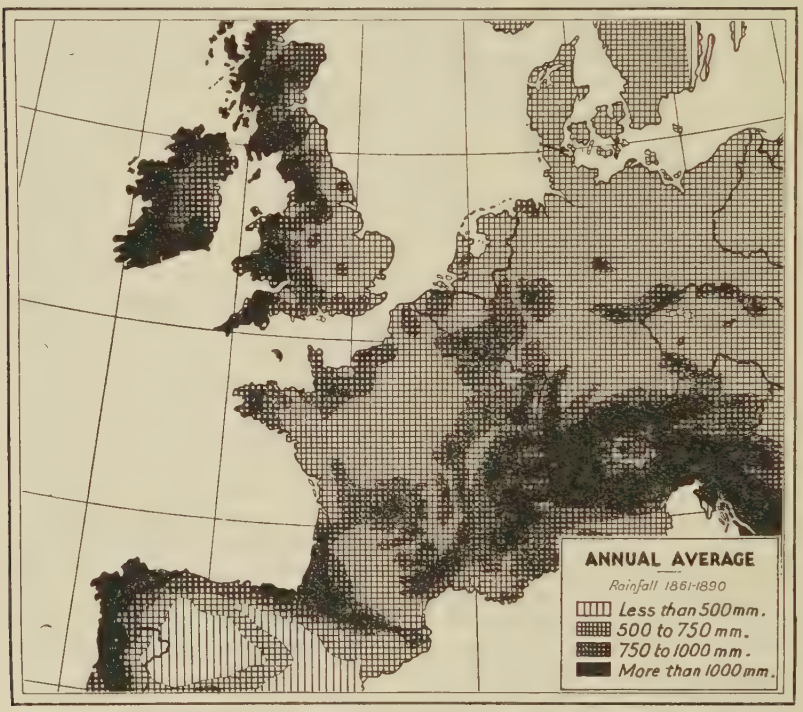

FIG. 5.—Map showing annual rainfall in Europe for the years 1861 to 1890. (After Angot)

available. Figure 5 shows a redrawing of Angot's annual mean rainfall map.[3] His monthly maps for April to September, inclusive, have been used in preparing Figures 6 to 11. Casual inspection will show at once that April is the month of least rainfall among those being considered; also that there is an increase each month until July, which has the maximum. August falls off very slightly as a whole, while September shows a decided drop, especially in the large area in Austria and Germany and extending eastward into the Russian Provinces. In the area of intensive white-pine blister rust outbreaks (fig. 4) the rainfall ranges from 1 to 3 inches in each of the

[3] In figs. 5 to 11 approximately 25 millimeters equal 1 inch; thus the range in rainfall shown in fig. 5 is 20 to 40 inches. In figs. 6 to 11 it is 1 to 3 inches.

months of April, May, and June, but it is constantly rising until in July practically all parts receive 2 or more inches. August remains the same except that the areas of greatest rainfall (over 3 inches) diminish in size and advance to the coast of the North Sea. In September the rainfall for the outbreak area remains high, but there is a decrease in central Germany which coincides in location with an area in which the blister rust seems to be absent or less virulent. The rainfall of Finland (*44*) follows that of the Baltic coast to the south quite closely. A comparison of these data with those for the two outbreak areas in North America, shows that they are very similar, but that there is less rain in the European area.

Records of relative humidity are not in such shape as to be given in detail. Hann (*61*), however, states that the relative humidity in

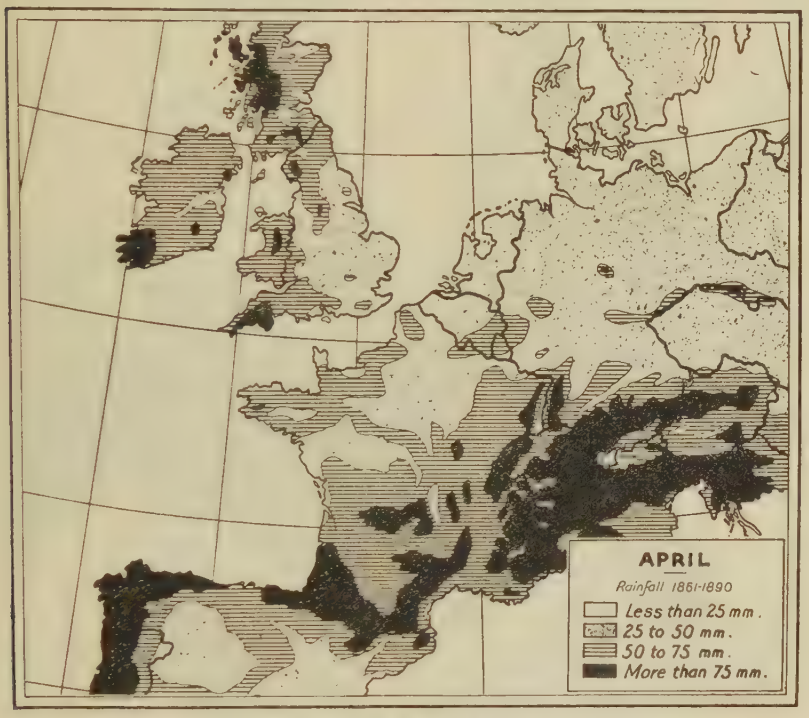

FIG. 6.—Map showing average rainfall in Europe for the month of April during the 30 years, 1861–1890. (Adapted from Angot)

July hardly falls below 75 per cent on the western coast of Europe. Since this is the case in midsummer, it can scarcely be less at other times during the warm season.

Cloudiness in western Europe is said by Hann (*61*) to attain a mean of 68 per cent. He also says that it decreases southeastward toward the interior of the continent.

Temperature records have been published as maps by Hann (*60*). These show annual isotherms for the world. The isotherms 35° to 50° F. include the areas in both Europe and America which have been designated as areas of special virulence of the white-pine blister rust. The isotherms 53° to 68° F. for July also include these areas.

These temperatures indicate a cool, temperate climate, conducive to high relative humidity, which must accompany a well-distributed rainfall, especially in the warm months.

While the rainfall in Europe is less than in North American outbreak areas, it is apparently more equally distributed during the warm season. The higher relative humidity of the air in Europe apparently more than makes up for any deficiency in actual rainfall. Also, the greater cloudiness of western Europe decidedly favors the disease (*163*).

Study of the records shows that this disease, in most North American localities to which it has penetrated, is able to maintain itself under average climatic conditions, but must have more than

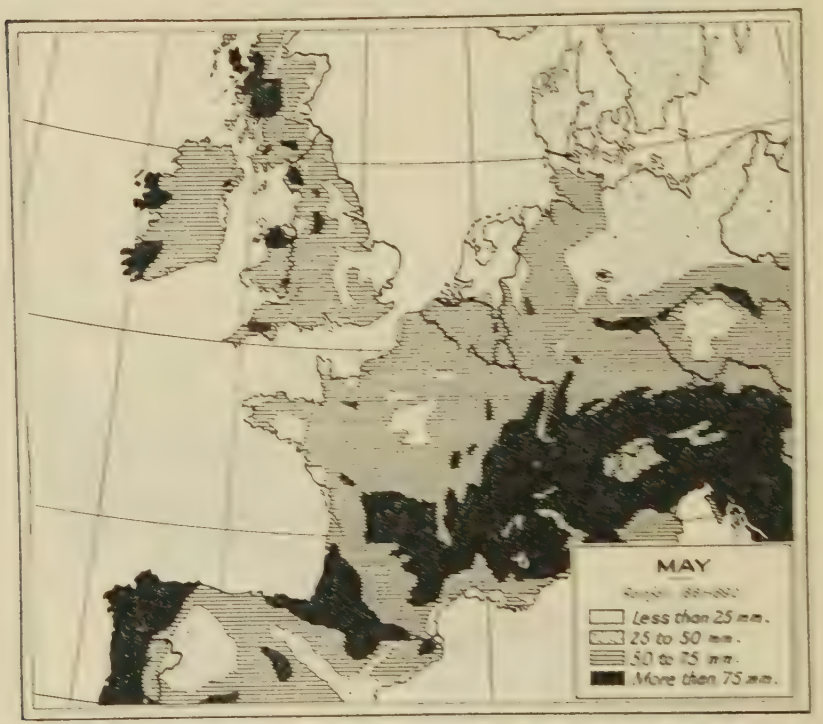

FIG. 7.—Map showing average rainfall in Europe for the month of May during the 30 years, 1861–1890. (Adapted from Angot)

average rainfall in the warm months to attain maximum virulence. In western Europe the disease has shown similar outbreaks in certain years, indicating plainly a dependence upon the climate. The known high humidity and cloudiness of western Europe are exceedingly favorable to the spread and propagation of the white-pine blister rust fungus (*163*), as they favor maximum longevity and viability of the spores by which it reproduces. On the whole, the climate of western Europe is as favorable for the progress of the disease as is that of our American outbreak areas, or more so. The special factor which has made the disease especially virulent in western Europe is the relative abundance and general distribution of *Ribes nigrum*.

INFLUENCE OF SMOKE AND FUMES ON WHITE-PINE BLISTER RUST

Observations upon the white-pine blister rust and its absence in a number of places where abundant fumes and smoke are present seem to indicate clearly that the disease is inhibited by them. It is supposed that SO_2 is the inhibiting agent (*119*). Hedgcock (*66*) noted the absence of other related rust fungi in an area affected by smelter fumes, although they were generally present outside that area. Long (*102*) found that mistletoe was absent in an area subject to smelter fumes. These appear to be the only published observations on this point. Yet it seemed to be the general opinion in the British Isles that city smoke and fumes prevent the white-pine

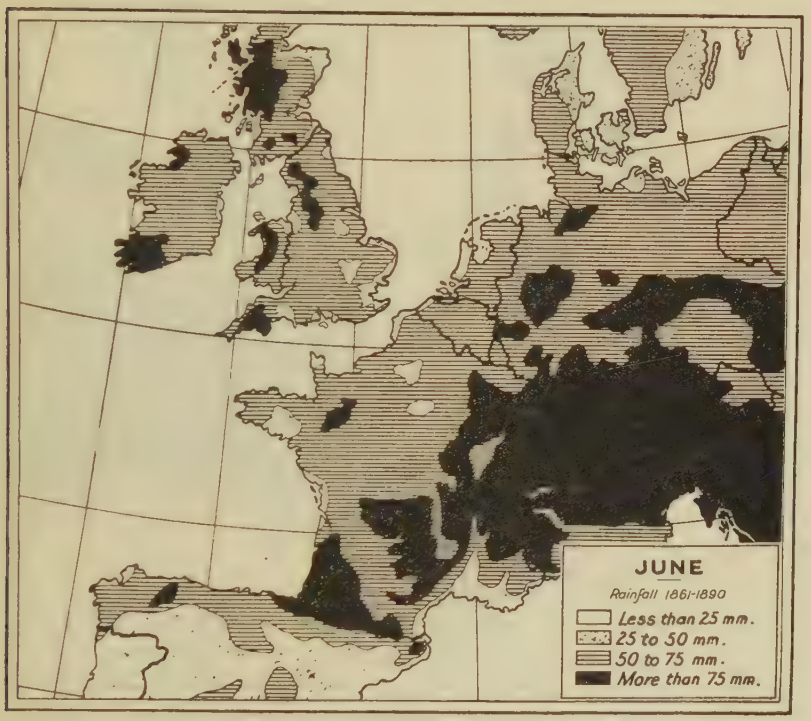

FIG. 8.—Map showing average rainfall in Europe for the month of June during the 30 years, 1861–1890. (Adapted from Angot)

blister rust. At Kew, where both Ribes and white pines are present and where *Cronartium ribicola* almost certainly must have been introduced, the disease has never been found, although it has been looked for many times. In the botanic garden at Edinburgh numerous susceptible species of Ribes are growing under and among groups of 10 species of the white pines. Here too the blister rust has never been seen, yet it is prevalent wherever *Pinus strobus* is grown in southern Scotland and in places north of Edinburgh.

In the same way, while the disease is reported from a number of places around Paris, France, it does not appear to have been found in the city proper. At Lyon no blister rust was found, although *Pinus strobus* and *P. excelsa* are growing in numbers in the

Parc de la Tête d'Or, and large bushes of *Ribes aureum* and several of the other species of Ribes are quite near. Here the limestone soil is believed to have an influence also. At Oslo (Christiania), Norway, Moir reports that blister rust does not occur in the botanic garden in the city but is widespread in the suburbs. At Prague, Czechoslovakia, some white pines (*P. excelsa* and *P. peuce*) were seen which were growing close to bushes of *R. aureum* and *R. alpinum*, but no blister rust was noted.

The Arnold Arboretum, near Boston, Mass., has numerous white pines, and near them are bushes of numerous species of Ribes. The blister rust has been found in various places around Boston but has

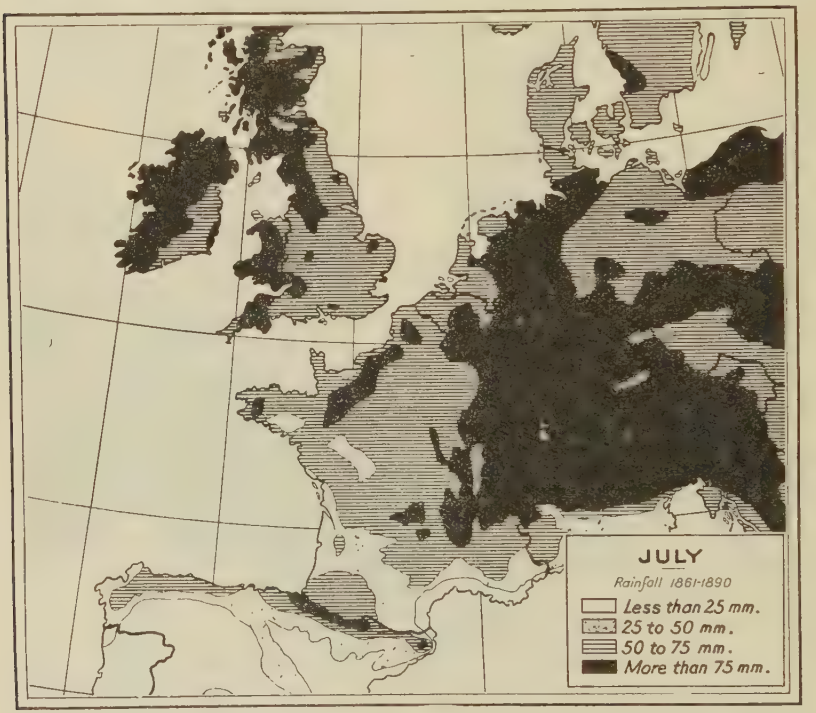

FIG. 9.—Map showing average rainfall in Europe for the month of July during the 30 years, 1861–1890. (Adapted from Angot)

never been reported from the Arboretum on pines. Only once was a sparse infection of it found and that on *R. nigrum* (*43*).

These numerous and widely distributed observations lead to the conclusion that there is something in the air of large cities which is injurious to the fungus *Cronartium ribicola*. The one thing common to the air of large cities is smoke or fumes from manufacturing plants bearing known injurious gases.

Special emphasis is given here to the effect of smoke and fumes upon the fungus because its spores are especially exposed to the action of such agents while blowing from one host to the other and when germinating. Undoubtedly fumes have an effect upon the pines as it is well known that the white pines are susceptible to injury

from industrial smoke and fumes. But at the specific places above mentioned the growth of white pines (a fair index of their well being) was reasonably good. The trees were by no means in a condition which would be called sickly. It is therefore believed that the effect of fumes on the pines can be ignored, especially as nothing is known of the conditions within the pine which influence normal infection by the blister-rust fungus.

INFLUENCE OF SCREENS ON INFECTION OF PINES

Studies made in North America have indicated that dense screens of foliage decidedly influence infection of pines by blister rust.

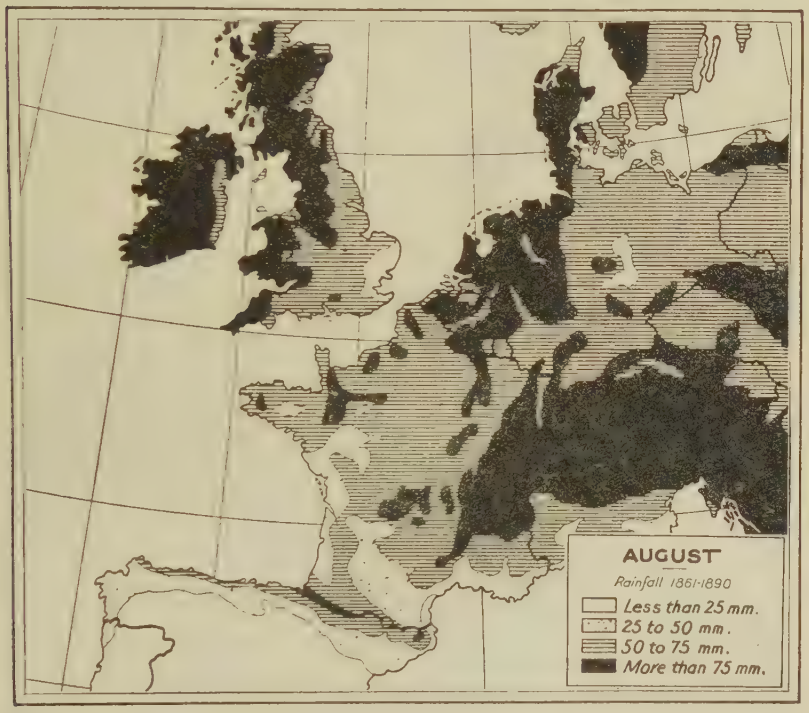

FIG. 10.—Map showing average rainfall in Europe for the month of August during the 30 years, 1861–1890. (Adapted from Angot)

Heavy screens of deciduous broad-leaved species over infected Ribes may prevent damage to white pines outside that screen (*158*, *160*).

Screens of other forest species located between *Pinus strobus* and Ribes are supposed to reduce infection. Some instances of this have been noted in North America, where the supply of sporidia was not excessive. In Europe, *R. nigrum* furnishes a superabundance of sporidia. Neither Boyce nor the writer saw there any instance of a screen, even of dense forest, appreciably reducing the resulting infection of white pines (*14*). Where a maximum supply of sporidia was present, groups of *P. strobus* at considerable distances from *R. nigrum* in the midst of heavy stands of other conifers taller than the white pines were as heavily infected as in pure stands of considerable

extent. The effect of such intervening screens is dependent upon the abundance of the sporidia in that general vicinity. If the sporidia are relatively scant the screen may have a noticeable effect in reducing infection, but if they are very abundant no screen will appreciably affect the infection of the white pines.

RELATION OF WHITE-PINE BLISTER RUST TO THE PINES

THE KNOWN PINE HOSTS OF CRONARTIUM RIBICOLA

The experience with *Cronartium ribicola* to date indicates that it is very closely limited to the group of true white pines. The success

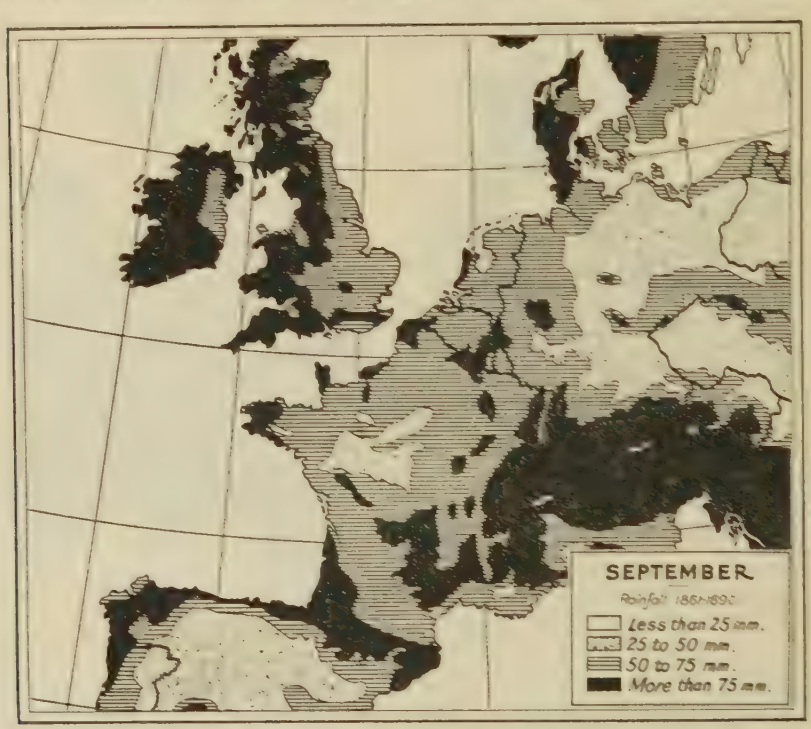

FIG. 11.—Map showing average rainfall in Europe for the month of September during the 30 years, 1861–1890. (Adapted from Angot)

of Clinton and McCormick (*22*, *23*) in artificially infecting young plants of *Pinus pinea* L. and *P. sabiniana* Douglas would lead to the supposition that it occasionally oversteps the limits of the true white pines, but it must be remembered that these infections have not yet produced aecia. On the other hand, neither have numerous artificial infections of *P. strobus* by Clinton and McCormick (*20*, *22*, *23*), York and Snell (*203*), and Spaulding (*155*, *160*). Inoculations by York, Snell, and Gravatt (*204*) have produced aecia on older trees. Tubeuf also got aecia from inoculations of *P. strobus* (*181*). The attacked plants of *P. strobus* have died, apparently from the effects of the disease, usually after pycnia were produced and before aecia would normally form. Tubeuf (*181*) and Clinton and McCormick (*22*)

have had inoculations produce yellow spots on the infected leaves of *P. lambertiana*. Spauling and Taylor (*160*) secured pycnia upon *P. strobiformis* Engelmann as a result of artificial inoculation of the leaves.

Actual findings in pinetums of Europe where the disease was present upon species of the white-pine group have resulted in no instance of any species of the pitch pines being found infected by *C. ribicola*. Thus practical experience, which usually is most reliable, indicates that infection of pitch pines will be accidental and probably rare if it occurs at all.

FIG. 12.—*Pinus albicaulis*, about 5 years old, infected by *Cronartium ribicola*. Note rough bark and small blister showing at upper edge of rough bark near base; also adventitious shoots at base. (Crawley, England)

The following pines have been found naturally infected by blister rust in the localities of Europe and North America mentioned below:

Pinus albicaulis. (Native from southern British Columbia to Washington, Oregon, and northern California, in the mountains only.)
England: Crawley (F. P. 38802).[4] (Fig. 12.)
Sweden: Harnosand. (Reported to Moir as attacked by a fungus like the blister rust.)
North America: Canada—Point Grey, near Vancouver, British Columbia (*28*).

[4] The letters F. P. followed by a number refer to a specimen in the Office of Forest Pathology bearing the number mentioned.

Pinus aristata. (Native in the Rocky Mountains from Colorado to California, northern Arizona, and New Mexico.)
England: Crawley (*24*).
Germany: Grafrath (*182*).
Pinus ayacahuite. (Native in Arizona, New Mexico, and northern Mexico.)
Belgium: Groenendael (Moir,[5] F. P. 37015, 37180).
England: Hollycombe (Moir); Horsham (Moir).
France: Massy-Verrieres (F. P. 37209).
Scotland: Stobo (Spaulding). (Fig. 13.)
Pinus balfouriana. (Native in California.)
Belgium: Groenendael (F. P. 37210).
Germany: Tharandt (*182*).
Pinus cembra. (Native in the Alps and from northern Russia through northern Asia.)

In Switzerland *Pinus cembra* is considered to be endemic and occurs over considerable areas at the higher elevations. In 1903 Schellenberg (*141*) found the blister rust on a single twig of *P. cembra* in the upper Engadine Valley. No other infections have ever been found upon native trees of this species, although Schellenberg has repeatedly looked for it and the writer gave especial attention to it in several different areas forested with *P. cembra*, including the upper Engadine Valley (*45*, *46*). It does not seem to the writer that a native fungus would occur thus rarely, especially as the side slopes of the upper Engadine Valley have abundantly scattered bushes of *Ribes petraeum*. The two hosts occur there close enough together so that the blister rust, if native, would have spread over that entire district. It seems more probable that the disease was originally native on *P. cembra sibirica* Mayr of Siberia or its variety, *P. cembra pumila* Pallas, in northeastern Asia. But the Siberian *P. cembra* is very susceptible, according to the available evidence. This would seem to indicate that *P. cembra sibirica* is not the original host; therefore the variety *pumila* of eastern Asia may prove to be the original pine host, especially as the fungus is reported from points well within its range (*160*, *168*). In cultivation, the Alpine variety, *P. cembra helvetica* Hort, is most common in all of the countries except Russia, Finland, and to a lesser extent Scandinavia. *P. cembra sibirica* is rather uncommon except near its native range. *P. cembra* is limited in numbers in cultivation, so that its susceptibility is not very thoroughly tested. In the following compilation of its susceptibility to attack by *Cronartium ribicola* the difference in susceptibility of the two varieties *helvetica* and *sibirica* must be kept in mind; also the presumption that *P.*

FIG. 13.—Tree of *Pinus ayacahuite*, 5 years old, showing infection of *Cronartium ribicola* at the base, with blisters just breaking through the bark. (Stobo, Scotland)

[5] Unpublished data secured by W. Stuart Moir in 1920.

cembra of the countries of Europe (except Russia and Finland) is the variety *helvetica* unless stated otherwise. The disease has been found upon this species of pine as follows:

Belgium: Groenendael (a single infected twig of *P. cembra sibirica*, F. P. 37181).

Finland: (Almost certainly the variety *sibirica*); Pitkaniana (Moir), Tammerfors (*37*).

France: Phillipsburg, Lorraine (*P. cembra helvetica*) (*50*).

Germany: Kammerswald, Schlesien (*P. cembra helvetica*) (*196*); Grafrath (*182*).

Russia: (Almost certainly the variety *sibirica*); Bolschow, Orel (*181, 182, 196*); Petrograd (*77, 106, 181*); Petrowskoje-Rasumowskoje, near Moscow (*83*); Tula Government (*86*).

Scotland: Murthly (Moir, F. P. 34992).

Sweden: Bispgarden (Moir).

Switzerland: Saas Fe (*133*); St. Moritz (*45, 46, 141*).

North America; Canada—Point Grey, near Vancouver, B. C. (*28*); United States—Massachusetts (*42*); Minnesota (*191*).

There are a number of places where *P. cembra* has remained healthy, although in the same locality *P. strobus* has been infected. These are of much interest because of the fact that the variety concerned is almost certainly *helvetica* in most instances. The following may be cited:

Belgium: Gedinne, a small plot of *P. cembra* remained healthy while *P. strobus* in an adjacent plot were badly diseased (Moir).

Finland: Mustila Arboretum, tested in considerable numbers. Presumably mostly variety *sibirica* (*173*).

France: Angers (Moir).

Germany: Bremen (*82*); Grafrath (*180*); Tharandt (*179*).

Norway: Jelsa, in a mixed planting *P. cembra* remained healthy while *P. strobus* was killed (Moir); Sandnes, a small plantation was healthy although near *Ribes nigrum* (Moir); Softeland, within 30 feet of heavily infected *R. nigrum* (Moir).

Scotland: Cultoquhey, a tree overhung a bush of *Ribes nigrum*, but no disease was noted by members of the Scottish Arboricultural Society (*137*).

Sweden: Alnarp, *P. cembra* healthy while 50 per cent of the *P. strobus* was killed (Moir).

Switzerland: Berne, an infected *Ribes nigrum* within 20 feet of a healthy *P. cembra*. The two have evidently been in the same location for at least several years. *P. strobus* everywhere in the vicinity is generally infected (Spaulding); Interlaken, *P. strobus* infected, but *P. cembra* healthy (Spaulding); Zofingen (Spaulding).

It is very noticeable in the preceding that *P. cembra helvetica*, so far as it is certainly distinguished, is quite or almost immune. It is equally noticeable that *P. cembra sibirica* is more susceptible. There are certain Russian accounts of the former remaining healthy while the latter was heavily infected in the same locality (*106, 141*).

Pinus excelsa. (Native of the Himalayas.)

This species ranks second in abundance and general distribution in Europe among the introduced white pines. It does not approach *P. strobus* in total numbers, being found scattered singly or in small groups. It has apparently not been given a real test in the forest, either in Europe or in North America. This, in the writer's opinion, is unfortunate, as it certainly is resistant to the blister rust. Repeatedly it was found unaffected, while adjacent *P. strobus* was more or less heavily infected. In timber qualities, production, and growth requirements it appears to approximate *P. strobus*. It will thrive in a limestone soil where *P. strobus* can scarcely exist (*9*). Its serious defects are snow breakage and tenderness to extreme winter conditions. It seems to the writer that it ought to be well tested on a forestry basis from southern New England and the lake region of New York southward, with a view to its possible substitution for *P. strobus* in critical situations because of the intensity of attacks of the white-pine blister rust. It should be considered also as an ornamental.

Pinus excelsa has been found infected in the following localities:

Denmark: Fugelsang Have (*99, 136*).

England: Bagley Wood, near Oxford (*153*).

Germany: Ihlten bei Lehrte (*116*).
Sweden: Alnarp (*113*).
Switzerland: Zurich (Spaulding, F. P. 37187).
North America: United States—Massachusetts (F. P. 2815, 25322); Vermont (F. P. 16981).

Places where *P. excelsa* was not infected, while *P. strobus* was attacked, are:
Belgium (*90*): Groenendael (Spaulding), Tervueren (Spaulding).
England: Crawley (Spaulding); Bagley Wood, near Oxford (Spaulding).
France: Angers (Spaulding); Nogent-sur-Vernisson (Moir) (Spaulding).
Germany: Grafrath (*180*), Tharandt (Spaulding).
The Netherlands: Putten (Spaulding) (*114*).
Switzerland: Berne (very striking case of resistance; Spaulding); Chur (Spaulding).

Pinus flexilis (native in Alberta and south in the Rocky Mountains to northern Mexico) has become infected by blister rust at the following places:
Belgium: Calmpthout (Moir says has been reported but not seen by him); Groenendael (Moir, F. P. 37016, Spaulding) (fig. 14); Tervueren (Moir, Spaulding).
Denmark: Charlottenlund (Moir, specimen at Agricultural High School, Copenhagen).
France: Nogent-sur-Vernisson (*114*, F. P. 34766, Spaulding).
Germany: Aschaffenberg (*180*); Fussen (*182*); Grafrath (*182*).
Norway: Fjosanger (Moir); Softeland (*114*, small plantation entirely diseased).
Sweden: Alnarp (*114*), 180 6-year-old trees were 69 per cent diseased; Lund (Moir); Stockholm (Moir); Upsala (Moir).
North America: United States — Massachusetts (*42*, F. P. 22058, 22258, 37249); Minnesota (*191*, F. P. 23087); Iowa (*125*).

FIG. 14.—*Pinus flexilis*, 20 years old, infected by *Cronartium ribicola*. Note the pycnial drops on the bark of the trunk just above the leaves of the adventitious shoots. (Groenendael, Belgium)

All experience with this species shows plainly that it is very susceptible to the attacks of white-pine blister rust. Moir saw it in considerable numbers (probably not less than 1,000 plants) especially in Sweden, Norway, and Belgium, and found it heavily infected practically everywhere. The writer's experience fully corroborates Moir's opinion that it is a very susceptible species. Moreover the writer, in a test with a small number of trees of this species, came to the same conclusion before visiting Europe (*121*). It has been found in the eastern United States freely diseased naturally also.

Pinus koraiensis (native in northeastern Asia) was found infected for the first time at Stockholm, Sweden (Moir, F. P. 34692).

Pinus lambertiana (native from western Oregon and California to Lower California).

This species has been distributed sparingly in Europe, where relatively few trees of this species are to be seen. As a rule those seen are infected. However, Tubeuf said that it is rarely grown in Germany and is very susceptible (Moir). It has become infected at the following places:

Belgium: Calmpthout (*117*), Groenendael (Moir), Tervueren (Moir, F. P. 36254, Spaulding).

England: Horsham (*114*).

France: Angers (Spaulding) (fig. 15), Nogent-sur-Vernisson (Moir, F. P. 34799); Spaulding, F. P. 37174).

Germany: Bremen (*81*), Grafrath (*180*).

Scotland: Murthly (*114*), F. P. 37011, 37013.

North America: United States—New York, Curry (Spaulding, F. P. 37097).

Pinus monticola. (Native from the coast region and interior mountains of southern British Columbia to western Montana, northern Idaho, Washington, western Oregon, and California.)

This white pine is grown in small numbers in Europe. It has been seen by the writer in but one forest planting, at Stobo, Scotland, where there is a block of approximately 100 trees about 25 years old. It is usually infected by blister rust wherever found in Europe and is plainly very susceptible. Experience in British Columbia, where the disease has attacked natural stands, shows it to be more susceptible than is *P. strobus.* It has been found diseased in the following places:

Belgium: Calmpthout (Moir).

Denmark: Egeland (Moir, specimen at Agricultural High School in Copenhagen).

FIG. 15.—*Pinus lambertiana,* about 10 years old, infected by *Cronartium ribicola* at the point where the white pitch has exuded. (Maulèvrie Arboretum, Angers, France)

Germany: Bremen (*86*); Tharandt (*16*).

Scotland: Balmoral (Moir) (F. P. 37014); Murthly (*97, 114* F. P. 37012); Stobo (Moir, Spaulding, F. P. 38801). (Fig. 16.)

Sweden: Harnosand (Moir reported that a fungus similar to blister rust attacked this species).

North America: Canada—British Columbia, the entire natural stand of the coast region is generally infected. There are scattered infections in the natural stands of the interior mountains. United States—New York, East Hampton, Long Island (F. P. 38243); Washington, Blaine (*108*).

Pinus parviflora. (Native in Japan and Formosa.)

This Asiatic species of white pine is relatively scarce in Europe and North America. It has been found infected twice as follows:

Scotland: Murthly (Moir, under the name *P. pentaphylla*).

North America: United States—Massachusetts, Hamilton (F. P. 22168).

Pinus peuce. (Native in the mountains of the Balkan region.)

It is scarce in cultivation in Europe. It appears to be a white pine which is really resistant to the blister-rust disease and also to be adapted to severe climates. Moir saw it in three different places in Europe, in all of which it was healthy when seen by him. The writer saw it in seven other places, there being no indication of the disease in any instance. Ten trees were the most seen in one place. It was reported diseased at Groenendael, Belgium, some years ago. Tubeuf also reported it diseased at Grafrath and Fussen, Germany (*180*). Recently, however, he states that at Grafrath this was a mistake due to immaturity of the trees and their being planted in mixture with *P. monticola*. The latter was diseased, but in every instance the *P. peuce* remained healthy (*184*). This appears to be a very severe test of its resistance. Tubeuf (*184*) has recommended it as a substitute for *P. strobus* in further tests in Germany, but calls attention to its possible deterioration in resistance by hybridizing with *P. strobus* or *P. monticola*, which may increase susceptibility of the progeny. Tigerstedt (*173*) has tested this species among others in Finland and reports it immune to blister rust where adjacent *P. strobus* trees are killed. Apparently he has used about 175 trees in his tests, which ought to give reliable results, as his trees are 13 to 17 years of age. His testimony is corroborated by Cajander (*17*) and Schenck (*143*). The latter knows the blister rust very well and says: "At Mustila, by the way, the five-needled *Pinus peuce* is immune from blister rust in a magma of *Pinus strobus* succumbing to it." Moreover, S. T. Dana recently visited the arboretum and carefully inspected the *P. peuce* trees, finding them perfectly healthy. Apparently here it has had a real test and has shown great resistance.

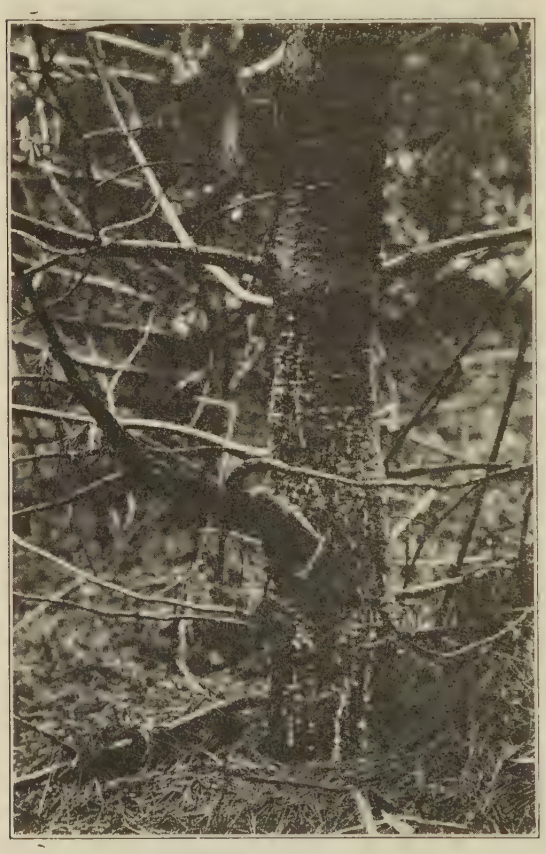

FIG. 16.—*Pinus monticola*, 20 years old, infected by *Cronartium ribicola*. Note the abundant blisters on trunk around the enlarged base of the branch on the left side of the tree. (Stobo, Scotland)

Pinus strobus. (Native from Newfoundland and the St. Lawrence Basin to southeastern Manitoba, the Lake States, and south in Pennsylvania and the southern Appalachians to northern Georgia.)

With the exception of certain areas mentioned under the heading "Influence of smoke and fumes on white-pine blister rust" (p. 21), *P. strobus*

in Europe is almost universally infected by *Cronartium ribicola*. An enumeration of the places where it has been found attacked would be practically a repetition of the places where this pine grows.

Figure 4 shows the distribution of the disease in Europe so far as it is definitely known. The shaded area is considered to be generally infected; the frequency of the disease within this area is dependent upon the frequency of *P. strobus*, its favorite pine host. The scattered dots show isolated places from which the disease is definitely reported.

In the judgment of the writer, the relative susceptibility of the different species of white pine is no different in Europe from what it is in North America (*161*). The difference between the two areas appears to be one of the sources of infection, with a slightly more favorable climate in western Europe.

RELATIVE SUSCEPTIBILITY OF THE PINES TO WHITE-PINE BLISTER RUST

In another paper (*161*) the writer has attempted to indicate the relative susceptibility of the various pines to the white-pine blister rust. Table 1 shows the tentative ranking of the species.

TABLE 1.—*Relative susceptibility of the pines to the white-pine blister rust, based upon natural infections only*

Immune	Resistant	Susceptible	Very suceptible
Pinus armandi	Pinus peuce [1]	Pinus cembra sibirica	Pinus albicaulis.
P. bungeana	P. cembra helvetica	P. strobus	P. flexilis.
P. cembroides	P. excelsa	P. ayacahuite	P. monticola.
P. monophylla	P. aristata	P. lambertiana	
P. parryana Engelmann	P. balfouriana	P. strobiformis	
P. edulis	P. parviflora	P. koraiensis [2]	

[1] This estimate is based partly upon published reports concerning this species.
[2] Changed on the basis of Moir's experience recently communicated by letter.

None of the species rated as immune have been tested in numbers large enough to give dependable results. Most of them are piñon pines, which are believed not to take the disease. None of the species rated as resistant, except the first three, have been tested extensively enough for more than a tentative rating. Since the publication of the previous rating (*161*), data upon the susceptibility of *Pinus peuce* have been found which indicate that it is even more resistant than was then known. Rather extensive tests have been made with it in Finland and Germany. In Finland it was in a mixture with *P. strobus* which was badly diseased, and it remained free from the blister rust (*173*). In Germany, Tubeuf writes that it has grown in mixture with *P. monticola*, which was heavily diseased and it remained healthy (*184*).

All of the species rated as susceptible take the disease rather freely, but a considerable percentage escape unless the attack is intense. Those rated as very susceptible take the disease so readily that they can not exist where the disease is present in conditions favorable for the spread of the parasite.

The foregoing rating is based upon infections which have occurred naturally. Turning now to the results of artificial inoculations, a different view is presented. Infection experiments are rather limited but the following may be considered. Tubeuf (*181*) in 1914 inoculated young trees of a number of different species of pines with the sporidia of *Cronartium ribicola*. In 1917 to 1919 Clinton and Mc-

Cormick (*22*, *23*) made inoculations upon different species of pines with sporidia of the blister-rust fungus. Tubeuf and Clinton and McCormick got positive results, and so far as known they are the only investigators who have successfully inoculated a number of different species of pines simultaneously. A few scattering successful inoculations have been made upon single species. A compilation of the results of these various inoculations may be of interest in contrast with what has happened naturally. (Table 2.)

TABLE 2.—*Results of artificial inoculations of various species of pine with Cronartium ribicola*

Not infected	Yellow spots produced	Pycnia produced	Aecia produced
Pinus cembra [1] (*22*, *23*, *121*, *181*)	Pinus canariensis	Pinus strobiformis [3]	Pinus strobus (*181*, *203*, *204*).
P. cembroides (*181*)	P. excelsa [3]	P. strobus (*20*, *22*, *23*, *87*, *157*, *160*, *203*, *204*).	P. flexilis [1] (*121*).
P. densiflora Sieb. and Zucc. [1] (*22*, *23*, *121*).	P. lambertiana (*22*, *23*, *181*).		
P. edulis [3]	P. pinea (*22*, *23*)		
P excelsa (*20*, *22*, *23*, *181*)			
P. flexilis (*22*, *23*, *181*)	P. sabiniana (*22*, *23*)		
P. koraiensis (*22*, *23*)	P. strobus (*87*, *203*, *204*)		
P. larico austriaca Asch. and Graeb. (*22*, *23*).			
P. massoniana Lambert [1]			
P. montana mughus Willkomm [1] (*121*, *181*).			
P. peuce (*181*)			
P. resinosa Aiton (*152*, *181*)			
P. sylvestris [1] (*22*, *23*, *121*)			

[1] Several trees of this species were tested on Block Island, R. I., by the writer in a plot where *P. strobus* and *P. flexilis* became heavily infected.
[2] Artificially inoculated by Spaulding and Taylor.
[3] Tested by the writer at Bethel, Vt., where the disease occurs naturally.

A comparison of Tables 1 and 2 shows very clearly that the conditions necessary for infection of pines have not been well understood. The failure to inoculate *P. flexilis* except under natural conditions, is remarkable in view of its demonstrated susceptibility under natural conditions in Europe. The testing of species of pines by planting them within severe outbreak areas is the most practical and satisfactory method of determining their susceptibility.

AGES OF TREES FOUND INFECTED BY CRONARTIUM RIBICOLA

The white-pine blister rust has been in North America about 30 years, but in most localities it has been present 15 years or less. It happens that none of the early outbreaks were in old stands of pine, so that even now little is known from actual experience in North America as to how serious it is on trees more than 75 years old. This was one of the principal points to be investigated in Europe, and abundant evidence was obtained to prove beyond question that white-pine trees of any and all ages are readily killed by this disease (*90*, *113*, *114*, *161*). (Figs. 17 and 18.)

The writer saw *Pinus strobus* trees of all ages from 4 to 118 years old which were plainly dying or had been recently killed by it. Absolutely no indications were noted that old trees are more resistant than middle-aged or young ones. The damage becomes evident earlier on small trees because the disease has relatively short distances to spread from the infected needles to the main branch and from that into the trunk. The trunk of the young infected tree is

girdled and the entire tree killed during the time needed for the disease to reach a main branch (perhaps still many feet from the trunk) in a large tree. As far as is now known the disease begins its attack in the needles or at their bases, and spreads as rapidly in the bark of an old tree as in that of a young one. Ordinarily it kills a tree by girdling the trunk. The only difference so far as the action of the blister rust is concerned between old and young trees is the difference in distance to be traversed in spreading from the leaves to the bark of the trunk.

FIG. 17.—*Pinus strobus* trees, 65 years old, dying from attacks of *Cronartium ribicola*. The height of the trees is about 100 feet. A, infection near fork in the top; B, the tree directly behind the man in the picture is practically dead. (Epinal, France)

Some old trees of *P. strobus* and presumably of the other white pines produce leaves from adventitious buds on the trunk and larger branches. (Fig. 19.) If these be attacked by the blister rust, direct entrance to the bark of the trunk is effected with the resultant early death of the tree. In this way trees 100 or more years old may be and are quickly killed. The discovery by Tubeuf (*181*) and by Clinton and McCormick (*20*, *22*, *23*) that the needles are common entryways for infection shows that as long as a tree has living needles it is open to infection. This is confirmed by the work of York, Snell, and Gravatt (*203*, *204*). Observations, as above stated, show that, regardless of age, a tree once affected is likely to be killed by the blister rust. These two facts can mean but one thing,

i. e., that the blister rust can readily attack and destroy white pines of all ages. Inherent resistance of an individual tree to infection appears to be the only factor intervening between it and destruction by blister rust.

It is a common practice in European forests to cull out defective trees annually or every two or three years. Trees of *Pinus strobus* recently killed or dying from attacks of blister rust are thus promptly removed and utilized. Consequently it is utterly impossible to learn what the actual damage in a stand has been, since more or less numerous trees are removed because of attacks by other fungi, windbreak, wind overthrow, and other destructive agencies, and the investigator can not attribute all or even a definite percentage of all missing trees to the blister rust.

In North America the death of trees of *P. strobus* that were dying or had been killed by blister rust was caused by girdling of the

FIG. 18.—*Pinus strobus* trees, 118 years old, near Rapperwil, Switzerland. Some of these trees were dead and dying from attacks of *Cronartium ribicola*. The trees are up to 135 feet tall. A, bases of these trees; B, top of same trees, showing about half their total height, above under story of beech, etc.

trunk. This has been true of trees of all ages. Some young trees have had many twig infections, but these thus far have not been numerous enough to kill the entire tree. In Europe trees of this species of all ages from 4 to 118 years (the oldest trees seen) were killed in the same manner, i. e., by girdling the trunk at or near the lower branches. In North America evidence is accumulating that trees of all ages will be killed.

Pinus monticola in British Columbia is commonly killed by girdling also. But some entire trees are killed by the death of practically all of the small twigs on the tree, resulting in practical defoliation.

RELATION OF VIGOR OF PINUS STROBUS TO ITS SUSCEPTIBILITY

There is a tendency even among plant pathologists to assume that a parasitic disease will not be able to become serious unless the host plants have been weakened in some way, thus making them susceptible to the parasite. This assumption holds good for some

diseases caused by organisms which have the power to become parasitic only under certain favorable conditions. But Raines (*129*) finds that with the rusts the vigor of the host and that of the rust correspond. *Cronartium ribicola* is an obligate parasite, and it appears that the well-being of the host pine is essential for the best development of the parasite.

In North America there are scattered among naturally reproduced trees of *Pinus strobus* certain individuals which plainly are in chronic poor health, make little growth, have but one year's leaves, and the leaves are more or less shortened and sometimes even partially dead. There are all degrees of such sickness, and it is commonly present in most stands of *P. strobus*. Observations show that trees plainly thus affected are rarely attacked by the blister rust even in the midst of heavily infected stands. On the other hand, it seems that the most aggressive cases of blister rust are on trees which have previously made the best growth and appear to be in the most flourishing condition. These observations can not be attributed to dominance of the latter trees making them most likely to receive sporidia of the fungus, as they hold good in thinly scattered stands where smaller trees have equal chances for infection.

FIG. 19.—Adventitious buds near the lower branches on a trunk of *Pinus strobus*. (Photographed by W. H. Snell)

In Europe there is the same relation between vigor of the tree and its susceptibility. On the island of Oland, Sweden, Moir found *P. strobus* forests upon an arid limestone soil. They had made poor growth, and the tree plainly was not in its element. The blister rust

was present, but was doing little damage, as it could apparently make but slow progress on these poorly nourished trees. About 175 miles distant is the island of Bornholm, Denmark. *P. strobus* is also present in forests on this island, where the growth conditions are better for the trees, as shown by their development. The blister rust there has done so much havoc that the white pine is considered a total loss. (Fig. 20.) In Oland the rainfall is scant, while on Bornholm it is abundant. This necessarily has influenced the amount of infection that has taken place, but it can not be held to affect directly the progress of the blister rust after it had entered the trees. This was where the great difference appeared. Similarly at Lyon, France, and at Lake Como, Italy, and Lake Lugano, Switzerland, where all of the trees of *P. strobus* seen had foliage of a sickly, yellowish green color and were manifestly not in a flourishing condition, the blister rust was absent. On the other hand, practically everywhere that *P. strobus* was seen in a flourishing state in all European localities by the writer the blister rust was also present and luxuriating. The above-mentioned absence of the disease from Lyon and the lakes is not entirely attributable to lack of introduction to those places, as it has reached localities relatively not far removed from them. Indeed, it has been reported from the Province of Como upon Ribes (*185*). Absence of Ribes can not be the cause, as they are grown to some extent in that section.

FIG. 20.—*Pinus strobus* in a plantation, about 35 years old, dying from attacks of *Cronartium ribicola*. Nearly every tree was similarly attacked. Note the resin exudation from the edges of the infected bark. (Bornholm, Denmark)

AGES OF INFECTIONS UPON WHITE PINES

The ages of infections upon *Pinus strobus* have been based upon the age of the affected wood (*160*). It was taken for granted that an

infection upon wood which was formed in the year 1921 was an infection dating from the fall of that year. This was done as a matter of convenience, as it was thought that it really might be an infection of any year after the summer that the wood was formed,

FIG. 21.—*Pinus strobus* trees, 65 years old, near Rapperwil, Switzerland, with blister-rust canker at the lower branches of one of them. Note the white exuded resin. This is characteristic of the older trees of this species

and it was considered best to err in making the age as great as possible rather than too little. Evidence showing that infection takes place through the leaves limits the possible infection period to two years in most cases (with *P. strobus*), three years in a smaller number of cases, and four years in a few instances, assuming that leaves

of all ages may become infected. As yet too little is known about the relative susceptibility of leaves of different ages to estimate their frequency of infection. Lachmund finds that the youngest leaves of *P. monticola* are relatively resistant to infection. Whether this will hold true for *P. strobus* is uncertain, since natural infections have taken relatively abundantly in the youngest leaves. But recent inoculations (*203*, *204*) show that 1 and 2 year old needles of *P. strobus* seem to take the disease with equal readiness. From present knowledge it may be said that an infection upon wood formed in 1920 (in the majority of cases) took place in 1920 or 1921. If it is in a tree that carries three years' leaves, the period must be increased by another year.

This presupposes that all leaves are formed in the same year that the wood upon which they are borne was formed—an assumption which is not always correct. Actual examination has shown that it is by no means rare for adventitious buds to develop leaves some years after the wood is formed in *P. strobus*. Meinecke called attention to this in western white pines, and it may be common to the white pines at least. (Fig. 19.) Adventitious shoots may and often do give the fungus direct entrance into the trunk of a tree, thus greatly shortening the life of the attacked tree. These adventitious shoots also greatly complicate the correct estimation of the age of an infection in a tree. Lachmund finds this can be done by a system of elimination. A tree carrying only two years' leaves and showing infection upon 1919 wood and succeeding that date may have been infected at any time after the summer of 1919. But if it is found that infections of the same relative stage of development are located upon wood of both 1919 and 1920, it may be assumed that the similar infections really occurred in the latter year. Especially is this true if similar infections are found located only on 1920 wood in some trees. It is more difficult to determine the age of the infections on trees which bear leaves 3 or 4 years old, but it can be done in some instances.

Pinus monticola regularly carries its leaves for four years and less often for only three. With this species it is rather easy to determine the age of infections while they are still young.

The age of old infections can not be ascertained accurately because of lack of reliable indicators of their stage of growth after aeciospores are once produced. Adventitious buds help to complicate matters also.

ABUNDANT RESIN OUTFLOW A SYMPTOM OF THE DISEASE

A symptom of the blister rust upon large trees in Europe is the very striking outflow of resin. This runs down on the smooth bark below the canker and turns white. (Figs. 15, 18, 20, 21.) It thus becomes very striking in appearance and is quickly perceived when one is looking for large trunk cankers, even if they are 75 or more feet above the ground. The outflow of resin is quite as abundant with some of the other blister rusts on the pitch pines, but on the rough bark it is not as conspicuous and usually does not turn so white. It is a very good field mark of the disease, cankers often being seen as a result of it which otherwise would escape notice.

During the last few years this symptom has become very common in America also.

CONTROL OF BLISTER RUST BY SECONDARY FUNGI

In a number of outbreak areas in North America it has been known that certain fungi enter bark cankers caused by the blister rust and permeate the diseased bark. They appear to grow faster than the blister-rust fungus, and the so-called "secondary" fungi quickly reach the surrounding healthy bark. There they stop, apparently not being able to attack the healthy bark. The blister-rust fungus is crowded out and often killed entirely. The secondary fungi appear to kill the attacked bark much quicker than does the blister rust alone (*132*, *160*). The identity of these secondary fungi is still unknown. They are not parasitic upon the blister-rust fungus but feed upon the pine tissues which are already attacked by *Cronartium ribicola*. These secondary fungi which attack the bark already diseased by blister rust may be abundant enough to influence materially the damage done by the blister rust. When the blister-rust canker is well out on a branch the secondary fungus kills the diseased bark, thus girdling the branch. That part of the branch beyond the girdle dies, and very often the blister-rust is killed either by the secondary fungus crowding it out or by the death of the tip of the branch. Thus nearly all of the cankers well out on branches with long internodes may be eliminated without reaching the trunk, where they would be sure to kill the tree.

Again, the secondary fungi appear to accelerate the girdling effect of the blister rust by killing all of the affected bark promptly, whereas the bark infected only by blister rust may remain alive at least a year or two after blisters are first formed (*132*). Posey and Gravatt found that about 15 per cent of all infected trees within a given limited area recovered from the blister rust by the action of secondary fungi and the natural suppression of side branches (*160*). Secondary fungi were noted as present and acting in like manner in numerous places in Europe which were visited by the writer in 1922.

One fungus, *Tuberculina maxima* Rostrup, is parasitic upon several of the blister-rust fungi (*Cronartium comandrae*, *C. coleosporeoides*, and *C. cerebrum*) here in North America (*193*). It is also reported as attacking *C. ribicola* in Europe (*98*, *99*, *179*). It was noted by Moir in 1920, attacking *C. ribicola* at Groenendael, Belgium, the island of Bornholm, Denmark, at Inval, England, and at Skien, Norway. In 1922 it was seen in abundance at Bornholm, Denmark; at Bagshot, England; at Grafrath, Germany; and at Groenendael, Belgium, by the writer. Its presence in two of these localities in the years 1920 and 1922 shows that when once established it is likely to continue in a place for some years. It appears that *T. maxima* is widely distributed in Europe upon *C. ribicola*. Although it is known upon several of our native American pitch-pine blister rusts (*193*), it has not yet been noted upon the white-pine blister rust in North America. This is probably accidental, but it seems a little peculiar. Whether this may mean that there are specialized races of *T. maxima* is yet to be determined. In Europe *T. maxima* has decidedly reduced the crop of aeciospores of *C. ribicola* in several places. At Bagshot, England, they were almost entirely suppressed in 1922.

On the island of Bornholm, Denmark, in the same year a large part of the aecia were abortive from the attacks of this fungus. This was true also at Groenendael, Belgium, and at Grafrath, Germany.

So promising was it in reducing the aecia of *C. ribicola* in Europe that at least one attempt has been made to use it artificially for this purpose (*98*, *179*). The results were not encouraging. This means of controlling destructive fungi is too erratic in results for artificial use, although it frequently happens that such parasitic secondary fungi may naturally assist decidedly in reducing the numbers of their hosts. They can be considered important only as contributory natural agents of control.

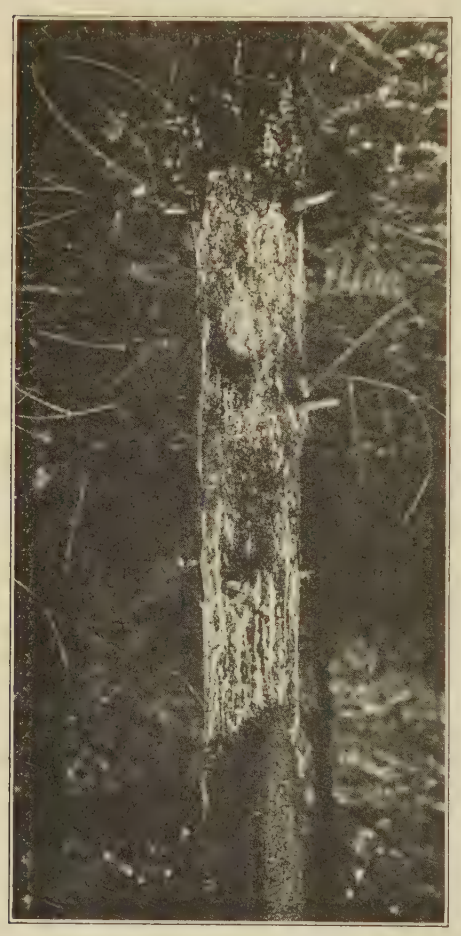

FIG. 22.—*Pinus strobus* infected by blister rust. The infected bark is largely eaten off by rodents. (Photograph near Murten, Morat, Switzerland)

CONTROL OF BLISTER RUST BY RODENTS

As early as 1917 squirrels were found to be active in reducing the crop of aeciospores on *Cronartium ribicola* in New England by eating the diseased living bark more or less completely off the cankers (*160*). Rarely does this result in the diseased bark being so completely removed that the blister rust is entirely prevented from making further growth into healthy bark beyond. Very often the twig or branch is so nearly girdled that the tip dies, thus hastening the death of the infected parts very decidedly. Squirrels may thus exert a decided influence upon the aeciospore crop of a locality or even of a large area, as Pennington and also Posey and Gravatt, independently, estimated the aecia-bearing pine bark thus removed in New York and southern New England to be 15 and 17 per cent, respectively (*160*). Similar extensive removal of infected bark of *Pinus monticola* by squirrels has occurred in British Columbia also.

The writer was much interested to see that the same thing was taking place in various forests of Switzerland where *Pinus strobus* was infected by *Cronartium ribicola*. (Fig. 22.) It is also known that *Arvicola glareola*, the field mouse, does the same thing in Denmark (*99*) and presumably in other parts of Europe. Probably this was the animal which had removed the bark of infected trees in

Switzerland. The same thing has been noted by Hedgcock in the western forests where *P. contorta* was infected by *Peridermium harknessii* (*68*). This was also noted by the writer in British Columbia in 1923. It is rather curious that animals of several different species and even different genera should acquire the same habit in such widely separated regions as Europe, New England, and the Rocky Mountains.

SEASON OF PRODUCTION OF PYCNIOSPORES

The writer has published the available data upon the season of the production of the pycniospores of *Cronartium ribicola* (*160*). Then the season was said to extend from June to the latter part of October. It was also believed that the action of forced specimens indicated that they might be formed naturally in early spring, but further experience has not shown this to happen. The normal season begins at the end of the aecial season (even while some aeciospores are still present) and apparently may last until cold weather. Dates are of no significance unless correlated with locality. Data for British Columbia are different from those for New England, being influenced by the climate, which controls the fruitings of this fungus just as it does the leafing out of the higher plants of a given locality.

In Europe the pycniospores are not produced in great abundance, partly because of the effect of *Tuberculina maxima*, which reduces locally their production in diseased bark, as well as that of the aeciospores. In Europe they were seen first by the writer June 21, 1922, in Belgium. In British Columbia on *Pinus monticola* they are produced in great quantities; indeed the dark pycnial spots often are so abundant that they coalesce and cover the entire pycnial zone of the diseased bark. The soured liquid is so plentiful in some areas on so many trees that, from the very noticeable scent, it is objectionable to one who is in the vicinity. This superabundance of pycnial liquid appears to be dependent upon the host. The smooth bark of *P. monticola* is decidedly thicker than it is in *P. strobus*, and this appears to favor the development of the fungus (*161*).

POSSIBLE IDENTITY OF WHITE-PINE BLISTER RUST WITH PERIDERMIUM PINI

Recently Eriksson (*41*) has advanced some opinions concerning the white-pine blister rust which might be taken on hasty reading to be proved facts rather than opinions. It may be that he did this with the purpose of awakening controversy to such a point that definite experiments would be carried out to test them and to settle once and for all the points in question. Certain of these points seem to need comment from the standpoint of American experience, also for the benefit of the field worker who is likely not to be able to decide them for himself, but who nevertheless must be as accurately informed as possible in order to make his work most effective.

In 1894, 1895, 1897, 1905, and 1910 Eriksson made a series of cross-inoculations with *Cronartium ribicola* and *Peridermium pini* Wallr.) Klebahn upon species of Ribes and *Cynanchum vincitoxicum* Moench., the known alternate hosts for the two fungi. Table 3 presents the data in the most intelligible form.

TABLE 3.—*Cross-inoculations made by Eriksson with Cronartium ribicola and Peridermium pini in 1894, 1895, 1897, 1905, and 1910*

Spores from—	Inoculated upon—	Results [1]
Pinus sylvestris	Ribes nigrum	11/61
Do	R. aureum	0/8
Do	Cynanchum vincetoxicum	0/47
P. strobus	Ribes nigrum	26/26
Do	R. aureum	0/4
Do	Cynanchum vincetoxicum	1/23
P. cembra	Ribes nigrum	38/38
Do	R. aureum	11/34
Do	R. rubrum	0/67
Do	R. grossularia	0/78
Do	Cynanchum vincetoxicum	1/24

[1] In the fractions in this column the denominator shows the total number of plants inoculated, and the numerator shows how many plants became infected.

These experiments were performed at the experiment station near Stockholm (*40*, *41*). Both rusts were present in that vicinity and at that season must have been producing myriads of aeciospores. It would be quite possible for spores of these fungi to be blown into an ordinary building or a greenhouse with the ventilators open, as they certainly would be in early summer. Eriksson (*40*) states that his first inoculations with *Peridermium strobi* upon *Cynanchum vincetoxicum* were made on a plant which had been brought from the forest a week before. This would hardly exclude infection before the plant was secured, although it appears that it did so in this case. Infection finally appeared after 51 days, an abnormally long period, which in itself is suspicious.

Inoculations were also made with *Peridermium pini* from *Pinus sylvestris* collected near Stockholm. Positive results were secured upon *Ribes nigrum* within the usual time for normal development after the inoculations were made. This, as Klebahn (*84*) says, might have been an instance of a single accidental infection which then multiplied to 4 after an interval of 12 days and again increased to 6 after another interval of 17 to 27 days. In the other tests the positive results with *Peridermium pini* on Ribes and *Peridermium strobi* on Cynanchum are so small in number that they may be due to accidental infections also. Klebahn (*84*) holds that Eriksson can not, on the basis of his experiments alone, consider that the two fungi are the same thing, especially since the aeciospores are morphologically distinct, and Eriksson did not examine the spores used to determine their identity. Klebahn also performed similar experiments with the two fungi, but on a very limited scale, which showed that the two are distinct (*84*).

The writer believes it possible for the aeciospores of one rust to be blown onto the spore masses of the other where both are abundant in the same locality, a mixture of the spores thus occurring which might easily give such results as Eriksson secured. In fact, care has been taken that this did not happen with inoculation material used in critical tests made by the writer and his associates. The material which Eriksson used was from aecia which were already broken open when collected, and some of the *Peridermium pini* he used came from the same locality as some of the *Cronartium ribicola*.

POSSIBLE STRAINS OR RACES OF WHITE-PINE BLISTER RUST

On the basis of his experiments, Eriksson believes that he has demonstrated the existence of races or strains of *Cronartium ribicola*. The very extensive experience of the writer and his associates in inoculating Ribes with this fungus shows that there is a very definite period in the development of a Ribes leaf when it is susceptible to infection by this rust. The susceptible period for *Ribes nigrum* is usually longer than that for any other species. That for *R. aureum* (including *R. odoratum*, etc.), is considerably shorter. It may very easily be that Eriksson's difference in inoculation results were entirely due to this cause alone.

Attempts have been made to determine whether there might be more than one race or strain of *C. ribicola* in North America, but with little or no indication that such was the case (*57*, *160*). This is not surprising, since it is definitely known that the fungus found in North America, as far as can be ascertained, has all come from Europe, and specifically from Germany, France, Belgium, and the Netherlands. The history of the spread of the fungus over Europe indicates strongly that those countries became infected from a common source. This source probably was Russia or Siberia. Finland is also a possibility, since it was reported from there nearly as early as it was known from any place (*37*, *100*). A single infected nursery could easily have started the disease in all western Europe, and this is believed to have been the case. Assuming that there is but a single strain of the fungus in the above-mentioned countries, the strain found in North America is the same. Whether variations have yet arisen in Europe or in North America is unknown, but rather extensive tests designed to show this have been unsuccessful.

POSSIBILITY OF TRANSMITTING WHITE-PINE BLISTER RUST BY MEANS OF SEEDS OF WHITE PINES

Eriksson (*41*, *pp. 9*, *10*) cites two lots of *Pinus strobus*, one of which became infected and the other not; the seeds came from two different sources. He assumes that the seeds must have been infected in one case and not in the other. Immense numbers of young white pines have been grown in North America from seeds imported from Europe, many of which must have been produced in Europe. In no case has the disease ever appeared upon such seedlings when they were grown in a locality known to be previously free from it. In many instances imported European seeds have been used in experimental work where the resulting seedlings were under very careful scrutiny, and in no single instance has there ever been a hint of the blister rust. Klebahn (*88*) experimented with *Peridermium pini* on *Pinus sylvestris* with this point in mind. He found that individual trees vary in susceptibility and that the source of seeds appeared to have no influence on susceptibility, probably because of indiscriminate interpollination in the forest. This would appear to prove that seeds do not carry this disease. It is not uncommon in North America to find trees of *P. strobus* which show no traces of the disease, although standing in the midst of heavily infected stands. There is an individual variation in susceptibility, as practically all field workers with

this disease will agree. This is a general rule for all fungous diseases, which is well known to all plant pathologists.

It would appear most probable that Eriksson's case was one of this kind rather than one of infected seed, which is an unknown thing. He states that seedlings of *P. strobus* were not shipped from foreign countries into Swedish nurseries, but he can hardly say that some private individual may not have shipped such seedlings unknown to him. It is the most probable way for the disease to have entered the country. Again, it is not impossible for aeciospores to have been blown from Bornholm, Denmark, or the vicinity of Copenhagen, or even from Finland, all of which places were reported as infected early, and thus to have started the first infection in Sweden, on *Ribes nigrum*. Eriksson's diseased *R. nigrum* bushes in southern Sweden (*41*) may very easily be caused by aeciospores blown from long distances, as experience in North America shows must happen (*120*).

Eriksson also cites old and young trees of *P. strobus*, the latter showing infection seven years before the former did. This again has happened in North America, but as long as infected Ribes were in the vicinity infection in either case has not been attributed to autoecious action of the aeciospores. In fact, no hint of autoecism has ever been detected with this fungus, although very careful observations have been made, and no experiments made to test this point have ever given positive results. The successful stopping of the spread of the disease in large areas in North America by the thorough removal of all Ribes is the best evidence that could be secured that these spores are not autoecious, since weather conditions have been favorable for pine infection to occur, as is shown by the amount of subsequent infection which has occurred in adjacent areas where Ribes were not removed.

Eriksson (*41*) says that wintering of the fungus on Ribes is proved but that "the morphological system of the fungus, by which this wintering takes place, is not clear as yet." He thus accepts the writer's evidence as to the proof of wintering and then ignores the writer's distinct statement that the wintering was by means of uredospores on dead leaves. The morphological system (or part) of the fungus by which it overwintered is perfectly clear.

Eriksson (*41*) also says that the outbreak of the disease on young seedlings must be derived from infected seeds. The experiences of numerous pathologists in North America is that infection of white pines never occurs except in the near proximity of Ribes. This has been more marked in North America (where *R. nigrum* is not plentiful) than in various countries of Europe seen by the writer, where *R. nigrum* (the worst species for causing white-pine infection to maximum distances) is relatively abundant.

The location of the fungus upon white-pine trees strongly indicates that it never infects the seed. It never yet has been known to attack the cones. There is little chance for infection of seeds to occur without adjacent parts of the cones also being attacked, as with the pine-cone rusts, *Cronartium strobilinum* (Arthur) Hedgc. and Hahn (*67*) and *C. conigenum* (Pat.) Hedgc. and Hunt (*69*). These rusts destroy the seed by stopping the development of the attacked cone, or part of the cone, before viable seeds are formed. Even with these rusts, it is doubtful if viable seeds ever become infected.

LIMITATIONS OF LOCAL CONTROL IN NORTH AMERICA

The white-pine blister rust has become thoroughly established in North America in the Northeastern States, in the Lake States, in the Northwest (*160*), and in Canada from the Great Lakes eastward and in British Columbia (*28*, *29*, *55*, *120*). The only course open is that of local control where the stand of white pines is dense enough and of sufficient local value (either present or future) to justify the expense of such local control measures. The principal control method of the present day is that of removal of all Ribes from the areas to be protected. There are areas of considerable extent where Ribes are so abundant and are so located that their efficient eradication is very costly. These are danger centers for *Pinus strobus*, which may be near them. They should be producing timber, as this is the most important use to which they can be put. If a full stand of *P. strobus* is to grow in such situations, it usually must be in part planted there. This suggests the use of species of white pine that are not so susceptible as *P. strobus* for planting in and around such danger centers, instead of undertaking the removal of the Ribes at high cost. There are such resistant species of white pines, but they are all foreign. Observations and reports show that *P. excelsa*, *P. peuce*, and *P. cembra* (Swiss variety) are very resistant to blister rust.

The writer would suggest and strongly recommend that these species be tested in critical areas in plantations large enough to furnish reliable results, both as to their resistance to the disease and their value as forest trees in the United States under favorable climatic conditions.

Pinus excelsa is hardy in southern New England. It is subject to breakage by heavy snows. Its evident field of use is from central New York to southern New England and southward. It will thrive in a warmer climate than *P. strobus* and can well be utilized south of the range of that species. It needs real forestry tests, but is known to be satisfactory as an ornamental.

Pinus peuce is scarce in cultivation in Europe. It is widely scattered in the countries west and north of its native range in the mountains of the Balkan region. It is reported as growing in Austria, Italy, France, Switzerland, Germany, Belgium, the Netherlands, Great Britain, Denmark, Finland, and Russia. In its native habitat it is found at the higher elevations where the climate is severe. Experience, so far as reported, appears to show that it does not thrive in mild climates but does well in rigorous ones, as in Finland, Russia, and the more extreme climates of Germany and France. Mayr, who studied trees foreign to Germany with special reference to their forestry properties, stated that if *P. peuce* had been known 70 years earlier it would have taken the place which *P. strobus* has made for itself in the forests of Europe. He says that the former has all of the properties of the latter, is very rapid growing, and frost hardy, and he recommends it as a substitute for *P. strobus* (*110*). Elwes and Henry (*38*) state that it is widely scattered in Europe and that cold does not seem to affect it, as it is growing at Petrograd. Tigerstedt (*173*), in tests of groups of trees of each species in Finland, finds *P. peuce* hardy and competing successfully with the native

species in the forest. Trees 13 to 17 years old had terminal shoots 30 to 35 centimeters long (13 to 14 inches). In North America it grows slowly at the Arnold Arboretum, but it is hardy. At Wellesley, Mass., a tree which is about 10 feet high is making growths of about 1 foot per year. It is growing in the New York Botanical Garden also.

Pinus cembra is a slow-growing species in most known situations. In Finland, however, it grew more rapidly than did *P. peuce* (*173*). Probably the variety thus tested was the Siberian, which is most susceptible to the blister rust. It may prove to be useful in the more northern regions, but needs careful testing to show its possibilities.

The timber qualities of these species as compared with *Pinus strobus* are not well known. In India *P. excelsa* is ranked as a second-class timber tree. Just what this may mean from our viewpoint it is difficult to say. *P. peuce* is still more uncertain as far as known, but Mayr (*110*) says it much resembles *P. strobus*. The wood of *P. cembra* is much used for wood carving in Switzerland. This would indicate an even-grained wood, soft in texture, and not too easily split. When the reports of poor quality of timber of *P. strobus* in Europe and the complete reversal of opinion there as to its value are considered, it would seem best for us in North America to wait and form our own opinions as to the value of the timber of these species when grown under our conditions. If it should be found that resistant species of white pines can be substituted for the more susceptible *P. strobus* and *P. monticola* in certain localities, some of the difficulties which now face us will be eliminated. This will be increasingly true as the more eligible areas are treated by our present methods and the more difficult ones are left for consideration. The writer believes thoroughly in the use of *P. strobus* in the Northeast so far as it is profitable. Just at present the increasing value of the timber of the broad-leaved trees is tending to lower eastern white pine in public estimation, and it is impossible to say how far this adverse swing of public opinion will go.

Instead of relying heavily upon the use of resistant species of white pines, it is high time that tests of these pines were begun on a scale large enough to settle definitely their status as to resistance and timber-producing value under our conditions. Such tests must continue for a long time to be of real value, and the sooner they are started the better. Other softwood species can be used in their place, as *Pinus resinosa* Aiton, *Picea canadensis* (Mill.) B. S. P., *Pinus rubra* Link, and *Pinus excelsa*, but that is not meeting the issue. There are reasons why the white pines are especially desirable, at least in certain sections.

THE POSSIBILITY OF GROWING WHITE PINES IN EUROPE

While in Europe the writer was asked whether he thought it possible to continue the growing of *Pinus strobus* in European forests. This question has come to the fore prominently in Germany in a controversy as to whether the white pines should be allowed to be grown or brought into the country (*183*). Since this is a matter that may come up in the United States, it has interested the writer. In

a recent paper (*162*) there was indicated what is believed to be a feasible method of growing white pines under European conditions with safety. Conditions in the Northwest in some respects resemble those of parts of Europe; hence the consideration of possibilities in one place may not be amiss in the other. Practically nowhere in Europe has the removal of all Ribes been tested in an adequate manner. The absence of wild Ribes makes the problem much simpler than in North America. The relative abundance of *Ribes nigrum* in Europe makes the removal of all Ribes difficult because of the opposition of the owners of the bushes. It would be necessary to make the safety zone much wider in Europe than in North America, as experience shows that damaging infection of *P. strobus* occurs at decidedly greater distances from the source of infection in Europe than has been the case in North America. However, it should be possible to choose areas for growing white pines in Europe that are far enough removed from extensive areas of cultivated land to allow the establishment of a safety zone of 2 miles, as a tentative extreme. At first the removal of all Ribes would probably be best, with the expectation that it might be possible, after it is learned just what happens, to allow resistant varieties of currants and gooseberries to be used. Under no consideration ought *R. nigrum* to be allowed within the safety zone or the inclosed forest area, as to it alone is due most of the damage in Europe from this disease.

SUMMARY

An investigation of the white-pine blister rust caused by *Cronartium ribicola* was made in 1922 in the various countries of northern and western Europe (Germany largely excepted). A comparison is made between conditions in North America and Europe which influence the disease.

In Europe, except for limited areas, the white pines are entirely introduced. The Ribes there are practically lacking in the wild state, except for special areas which appear to be limited in extent. Cultivated Ribes are in nearly every garden of the entire region where the white pines can grow successfully. *Ribes nigrum* is a great favorite and is found practically everywhere that Ribes grow. To it is due practically all of the pine infections seen in Europe. It is far more abundant than anywhere in North America. The white pines are generally considered to be of far less value than are the black currants, hence no efforts have yet been made to combat the blister rust in an effective way.

Pinus strobus is the favorite pine host throughout Europe, and, as far as the discontinuous distribution of this species will permit, the region of abundant and frequent rainfall during the warm months—western and northern Europe—is generally infected.

Investigation shows that certain species of the white pines are resistant to the blister rust. These are *Pinus cembra helvetica*, *P. peuce*, and *P. excelsa*. There may be others, but too few trees of any of them have been seen in disease areas to permit conclusions to be drawn. The writer suggests that these species be tested in numbers large enough in several different places so that their forestry qualities, as well as their resistance to the disease, may be definitely determined.

For Europe, the writer suggests that the removal of *Ribes nigrum* within certain chosen forest areas and for a reasonable distance outside would make it possible to grow the white pines safely and with a minimum of inconvenience.

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